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THE MOVEMENT AND IMPACT OF PESTICIDES USED FOR VECTOR CONTROL ON THE AQUATIC ENVIRONMENT IN THE NORTHEASTERN UNITED STATES

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Arthur D. Little, Incorporated

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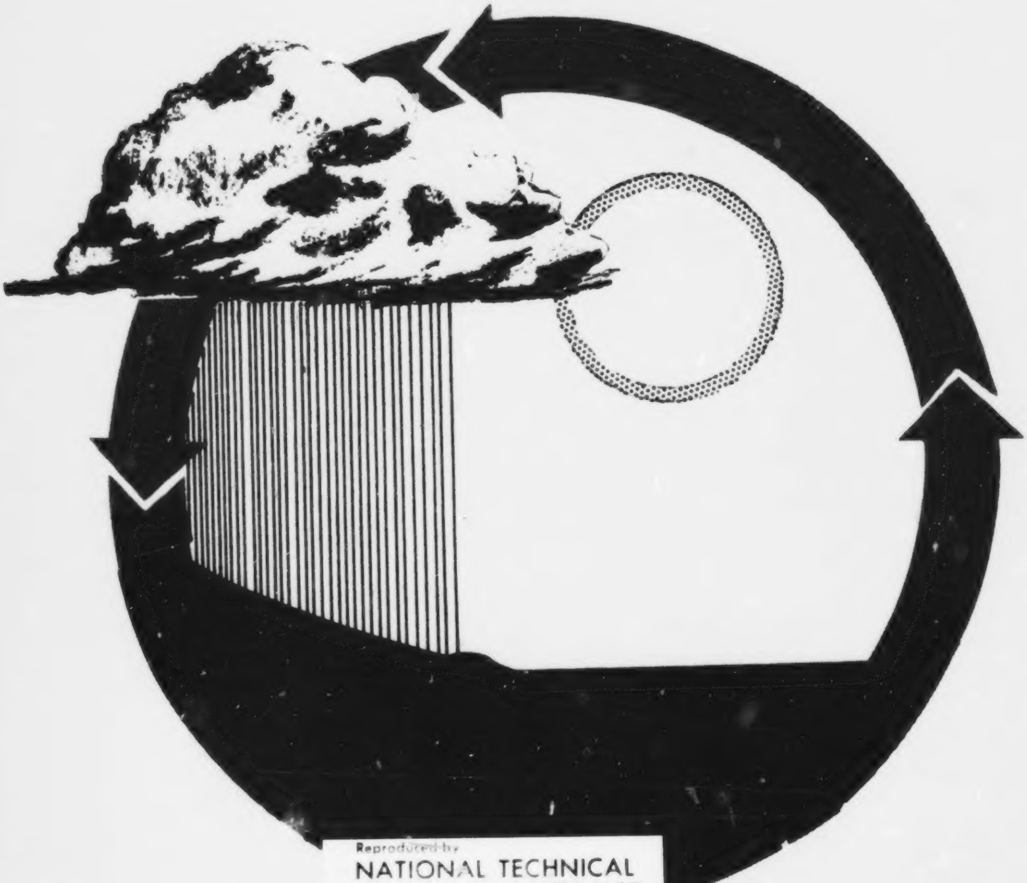

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THE MOVEMENT AND IMPACT OF PESTICIDES USED FOR VECTOR CONTROL ON THE AQUATIC ENVIRONMENT IN THE NORTHEAST

PESTICIDE STUDY SERIES - 9

THE MOVEMENT AND IMPACT OF PESTICIDES USED FOR VECTOR CONTROL ON THE AQUATIC ENVIRONMENT IN THE NORTHEASTERN UNITED STATES

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ENVIRONMENTAL EFFECTS OF PESTICIDES USED FOR VECTOR CONTROL IN THE NORTHEASTERN UNITED STATES

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Introduction

In the northeastern United States the mosquito abatement programs are conducted for the vector control of Eastern equine encephalitis, to reduce the nuisance problem caused by mosquitoes, and to enhance recreation areas. Typically, these programs consist of the application of pesticides (vectoricides) and the drainage of stagnant water. Unfortunately, pesticide applications are often made without proper safeguards to prevent damage to the aquatic environment.

Almost all aquatic organisms spend at least part of their life cycle in the salt marsh and estuarine areas or depend on a steady flow of nutrients from these areas where migratory birds and waterfowl are regular visitors. Damage to aquatic environment is of concern to the commercial fishing industry and to those who enjoy the aesthetic values of recreational areas in the region.

This report summarizes a case study concerning an in-depth investigation of a specific vectoricide use situation documenting the kinds and quantities used, their route from the point of initial application into the water environment, their ultimate effect on the ecosystem, and the laws and regulations which affect their use. Cape Cod was chosen for this study because it is an important commercial fishing center and the most popular seashore recreational area in the Northeast. It has a long history of mosquito abatement programs which formerly included the use of persistent vectoricides but in recent years has been limited to easily degradable light mineral oil. With this treatment history, the area affords an opportunity to study the long-term effects of vectoricides without interference from effects caused by recent applications.

The Bass Hole Marsh in Dennis and the Herring River Marsh in Harwich were selected for intensive study to compare the effects of treatment programs on the north and south shores of Cape Cod. A literature search was conducted and interviews were held with concerned officials, businessmen and private citizens throughout New England. Additional field work was undertaken in the two marshes to observe the effects of vectoricides on the aquatic environment, and soil and water samples were analyzed to check the general level of vectoricide residues.

Findings and Need for Action

Inventory of Uses

In New England, malathion was the principal chemical compound used in 1970. It was used as both a mosquito larvicide and adulticide, and it accounted for nearly 60% of the total quantity reportedly used in the various states, as shown in Table 1. Although pesticide consumption records are generally inadequate to permit precise estimates of use patterns in most states (New Hampshire is the lone exception), it is generally believed that the use of malathion has increased at a rate which matches decreases in the use of DDT and other persistent chlorinated hydrocarbons. Methoxychlor, which is a relatively nonpersistent chlorinated hydrocarbon, is also increasing in popularity as a vectoricide. Abate, naled, and carbaryl are gaining in importance. Other chemical compounds used include carbofuran, fenthion and DDT; Maine was the only state reporting the use of DDT as a vectoricide in 1970. None of the New England States permits the use of DDT as a vectoricide after 1971.

TABLE 1

QUANTITIES OF PESTICIDES USED FOR INSECT VECTOR CONTROL IN NEW ENGLAND, 1970

(lbs. of active ingredients)

	Conn.	Maine	Mass.	N. H.	R. I.	Vt.
Malathion	550	410	32,000	4,100		X
Methoxychlor		420	10,550	3,804		X
Naled		152	4,430			X
Abate			3,100			
Carbaryl				2,626		X
Others	160	42	1,140			X
Total	710	1,024	51,220	10,530	N.A.	N.A.

N.A. = Not available

Source: Connecticut State Department of Health
Maine State Board of Pesticides Control
Massachusetts State Reclamation Board
Rhode Island Department of Natural Resources
New Hampshire Pesticide Control Board

Vermont: Pesticide Advisory Council and
Division of Plant Pest Control,
Department of Agriculture

Vectoricide use on Cape Cod as reported by the Cape Cod Mosquito Control Project is shown in Table 2. On Cape Cod,

TABLE 2

MOSQUITO LARVICIDES USED ON CAPE COD, 1930-1971

Period	Material	Final Formulation	Quantity (Active Ingredients)
1930-1942	Fuel Oil	-	Not recorded
1930-1942	Pyrethrums	Various	Test quantities only
1945-1956	DDT	6.25% in fuel oil	2500 lbs/yr
1957-1961	Fuel Oil	Surfactant 1:400	4000 gals/yr
1957-1961	Dieldrin	2% granular	200 lbs/yr
1962-1965	Abate	2-1/2 oz. in 50 gals. water	160 lbs/yr
1962-1965	Paris Green	10% granular	800 lbs/yr
1966-1969	DDT	10% granular	400 lbs/yr
1966-1969	Malathion	2% in fuel oil	250 lbs/yr
1970-1971	Larvicide Oil	As received	3000 gals/yr

Source: "History of the Cape Cod Mosquito Control Project, 1928-1971"

concern about the potential for adverse effects on the environment was instrumental in curtailing the use of persistent chlorinated hydrocarbon insecticides such as DDT and dieldrin in favor of more readily decomposable phosphate insecticides. However, even these materials have now been discontinued, and the sole vectoricide reportedly used on Cape Cod in 1971 was mosquito larviciding oil. There are no reports of mosquito adulticiding work on Cape Cod.

Cape Cod includes 50 square miles of salt marshes and 5 square miles of freshwater swamps in addition to 170 great ponds (above 10 acres). In the past ten years, an average annual use of 650-950 pounds of pesticides (active ingredient basis) has provided acceptable control of mosquitoes on these 32,500 acres. These low rates of application were accomplished by making spot treatments by hand to only those stagnant pools and puddles where large numbers of mosquito larvae were identified. Thus, with proper timing and precise placement, the quantities of vectoricides can be held at low levels.

In the Bass Hole Marsh in Dennis (Chase Garden Creek section) and the Herring River Marsh in West Harwich, we carried out intensive studies of the uses, effects, and residues of vectoricides. The quantities and products reported in use followed much the same pattern as elsewhere on Cape Cod (Table 3).

TABLE 3

MOSQUITO LARVICIDES USED IN TWO CAPE COD MARSHES

(cumulative, active ingredients)

		Bass Hole (Dennis)	Herring River (W. Harwich)
1961-1965	Fuel Oil	80 gals.	53 gals.
1966-1970	Abate	0.2 lbs.	0.2 lbs.
1966-1970	Malathion	33.8 lbs.	7.6 lbs.
1970-1971	Larvicide Oil	30 gals.	12 gals.

Source: Data supplied by Cape Cod Mosquito Control Project

During the period 1961-1965, the principal larvicide was a mixture of common fuel oil plus a surfactant to permit even spreading and application. Small quantities of Abate were used in 1966-1970, together with slightly larger quantities of malathion. The quantities of each material used in individual years during the period was a function of the severity of larvae build-up. The work crews of the Cape Cod Mosquito Control Project were instructed to apply vectoricide only after the need had been identified and measured. Furthermore, the practice was to treat only depressions where water remained at low tide, thus only a relatively small portion of the marsh was treated. The areas studied cover over one square mile each, or more than 1280 acres, but quantities used suggest that much less than 1 percent of the surface was treated.

Beginning in 1970, and continued in 1971, a larviciding oil was again used in both of these marshes. Unconfirmed reports indicate that the new larviciding oil is not completely satisfactory, since it does not always kill quickly and requires repeated visits to treatment areas in order to check the completeness of kill.

Need for Action--State agencies should be given the authority and funds needed to develop records of pesticide consumption in sufficient detail to permit analysis of data to identify use patterns, and promote more effective monitoring and control.

Methods of Application

In New England, mosquito adulticiding normally is done by machine, and the ultra low volume (ULV) method has become the most widely used. Both thermal and cold fogging machines are used, and offer the advantages of covering large areas with well dispersed aerosols in short periods of time. Indiscriminate use, however, may lead to wind drift and application of pesticide chemicals directly to live waterways.

High volume equipment is seldom used for mosquito control by mosquito abatement organizations but it is commonly used by cities and towns to spray large trees. In densely populated urban areas there is little open soil to absorb run-off and drip, and this method permits entry of pesticides into the water environment through the storm drain system. Pollution from this source is often attributed, wrongly, to mosquito abatement activities.

Larviciding, when done by hand, can be controlled precisely to treat only those pools that are heavily infested. Spot coverage averaging less than one percent of salt marsh areas has proven successful on Cape Cod. Larviciding by machine, on the other hand, cannot be controlled as precisely and some non-infested areas are treated.

Major materials used for larviciding in New England include a two percent solution of malathion in fuel oil, a similar solution of methoxychlor, a water solution of Abate varying from 0.05% to 0.10%, and mineral oils which are refined especially for use as larvicides. Surfactants may be used with all of these liquid formulations.

Granular formulations of the above materials are also available throughout the area. Formulated on sand and other carriers at low concentrations, these materials can be spread mechanically by aerial or ground equipment. Hand spreading may not be feasible because of the acute toxicity of the materials.

Route Into Waters

Vectoricides enter the aquatic environment through both intentional and accidental means. Intentional is more important in New England, since vectoricides are applied in and around swamps and marshes; subsequent rains or flooding may move the materials directly into the water environment. Wave and tidal action in salt marshes may also move vectoricides from the point of application into the liquid phase and distribute them to other areas. Nonresidual materials (such as organophosphates, carbamates, mineral oils, etc.) do not move far from where applied since decomposition to harmless forms occurs rapidly.

The practice of applying vectoricides to storm drains in urban areas may lead to direct contamination of the aquatic environment. Even light showers may generate sufficient run-off to rapidly transport minerals from the individual drains to outflows. Highly toxic materials thus transported can have significant acute toxicity effects on nontarget organisms, particularly if showers occur soon after the pesticide is applied.

Substantial quantities of pesticides are used for agricultural purposes in New England, but are normally adsorbed by soil particles and held in place until degraded. Pesticides applied to cranberry bogs, however, may be released into the aquatic environment when bogs are improperly drained.

Accidental means of pesticides entering the aquatic environment include spills during handling, transportation and storage. Trucks which transport pesticides to distribution points in New England have been involved in accidents which resulted in broken containers and loss of material. Prompt handling (detoxification and clean up) by specially trained crews of experts (under the direction of the National Agricultural Chemicals Association's Pesticides Safety Team Network) has averted disaster to humans and large animals, but the traces which remain have the potential for water contamination. Improved and more durable packaging, economically possible with the more expensive vectoricides currently used, should reduce accidental release.

The disposal of empty containers is a serious problem in New England. Some states have issued clearly defined regulations identifying both the prescribed methods and correct disposal sites, but have experienced significant difficulties in getting municipalities to implement them. Most local health officials appear to place low priority on the problem, and as a result there are few disposal systems that have set aside land fill areas specifically for this purpose. Also, many localities do not have proper land fill areas and containers cannot be buried. During our study we noted considerable reluctance among commercial pesticide users to discuss this problem, since many are not able to comply with the regulations.

Once released into the environment, pesticides move by several means. Principal mechanisms for vectoricides in New England appear to be: (1) sediment transport, where compounds are adsorbed to finely divided particles of soil (clays) or organic matter, and (2) atmospheric transport of their volatile fractions. Since most soils on Cape Cod are sandy and with low clay contents, pesticides more commonly adsorb to organic matter such as mulch, bark, straw, leaves, etc. Heavy showers, tidal action, and flooding move these easily, but the rate and direction of transport can be predicted. Less is known about atmospheric means of transport.

Need for Action--Regulations regarding the disposal of empty pesticide containers should be improved and standardized throughout the New England states. Provisions should be made to check the adequacy of local disposal areas.

Impact on the Environment

There is a limited diversity to the flora and macrofauna (fish, birds, mammals) in the two salt marshes we studied; however, there is a great diversity of microfauna. In addition to the mosquitoes and other insects that inhabit these areas, there are innumerable invertebrate larvae, worms and shellfish. The marshes act as efficient energy nutrient traps and supply a major portion of the food for commercially important fishes which pass Cape Cod in seasonal migrations. Tidal action distributes the food to each life form both within and at the mouth of the marsh, and this periodic flushing by the tide results in a rapid turnover of materials.

Simply put, the food chain in these salt marshes begins with salt grasses which decompose via machine action to detritus. The detritus, algae and diatoms, are consumed by small fish, shellfish and other filter feeders. Larger predator fish, eels, and lobsters, are at the top of the food chain. The effect of birds is minimal when compared to the total system. The interrelationships between prey and predator provide for a complex web. These organisms carry out their life cycle in the water, or land periodically covered by it, in close association with each other. One species may serve as prey for another species during early stages of development, but the roles are reversed later.

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We surveyed the literature for both the acute and chronic effects of Abate, DDT, malathion, and mineral oils on typical salt marsh organisms. Abate, which kills mosquito larvae at a concentration of 11 parts per billion (ppb) or less, must be present at a concentration of greater than 1 part per million (ppm) to affect juvenile killifish. DDT, which is not now used for mosquito control in New England, kills juvenile killifish at only one-fourth the concentration needed for mosquitoes and also may concentrate to toxic levels in animals high up in the food chain. Malathion is not toxic to minnows at the concentration used for larvicide work. Mineral oil (Flit MLO) has no effect on mummichogs at application rates greater than ten times that required for mosquitoes.

Our observations indicate that there is no measurable long-term effect on the typical biota found in these marshes which can be attributed to the materials and treatment techniques used by the Cape Cod Mosquito Control Project. Maximum vectoricide treatment levels have been consistently below the levels necessary to affect more organisms. According to their data, the Project's highest application rate was 0.02 lb. malathion per acre to a limited area of the marshes; even if localized mortality occurred, the effects would be quickly neutralized by repopulation from adjacent areas.

It is our general conclusion that the local, spot application of vectoricides as practiced during the past ten years by the Cape Cod Mosquito Control Project to the stagnant waters at the fringes of the marshes does not produce a risk of significant toxic effects to important species. Our analysis has included species of interest for commercial and aesthetic considerations. No human health problem has been predicted.

Degradation and Metabolism

Studies of pesticide metabolism are helpful in reaching rational assessments of hazards arising from their use.

Most compounds used for mosquito control are complex, synthetic organic chemicals, and the action of natural processes (chemical or microbial) produce degradation products which have different properties and effects on the environment. In order to understand the potential effects on nontarget organisms from the treatments used in the two marshes, the literature was surveyed for studies dealing with those chemicals. In the light of these findings, soil and water samples from these marshes were analyzed to determine how much of the chemicals used (or their degradation products) were present. Although the scope of the program was limited, and the results from our testing program are not statistically valid, we believe that the results are indicative of the general levels of pesticides that are residual in those two salt marshes.

The major breakdown products of DDT is DDD and DDE, and these, together with DDT, have been found up to ten years after its application. The quantities found, however, are a function of the particular environment; in moist, fertile soils, DDT may disappear in a few months, but up to 30 percent may be retained after ten years in the upper, organic layers of forest podosols. In general, it appears that DDT tends to degrade more rapidly where a large and varied soil microbe population is present, and persist for the longest periods of time in environments such as aquatic and other areas where microorganisms are more limited in number and kind. The amount of nutrients available for growth of microorganisms also is of importance.

Dieldrin is more resistant to breakdown than DDT but on exposure to sunlight is likely to form photodieldrin, which is more toxic to rats and pigeons than dieldrin and less toxic to certain fish. Aldrin and several unnamed metabolites are formed by the actions of a number of microorganisms, but most species of soil microbes are incapable of degrading dieldrin. Most studies classify it as a highly resistant compound, with major losses from soil by means of volatilization and sediment transport.

Malathion is less stable than most other insecticides, and may be degraded within 24 hours of its application to some soils. Biodegradation appears to be the major means of decomposition in aquatic environments, although aeration alone has some effect. Biological oxidation of malathion produces malaoxon, the active insecticidal compound, which undergoes a parallel degradation route. Other malathion degradation products are relatively harmless, particularly in the small quantities which can be found at any one time in the environment.

Abate is a newer material, and fewer studies have been conducted with it. The major degradation products seem to be its sulfoxide and sulfone derivatives, neither of which have been extensively tested for their effects on typical aquatic biota. Abate is somewhat more resistant to degradation than malathion, but the limited studies that have been conducted seem to indicate that Abate is not deleterious to nontarget organisms. We suggest further research on its degradation and metabolism should be undertaken.

Historical vectoricide treatments in the two salt marshes on Cape Cod included the four chemicals discussed above (DDT and dieldrin were used prior to 1961, and dieldrin is currently recommended for insect control in cranberry bogs in the area). Samples of soil and water were taken from the general areas where these vectoricides had been applied and where observations of effects on typical biota were made. In consultation with our analytical chemists, analyses were carried out by Dr. Karl Deubert of the University of Massachusetts Agricultural Experiment Station at Wareham. Dr. Deubert has been active in determining soil pesticide levels on Cape Cod, and was able to correlate these results with those done earlier.

The general findings were as follows:

- Residue levels are low, averaging 0.026 ppm DDT, 0.007 ppm DDE, and 0.021 ppm dieldrin.

- No evidence of malathion or Abate was found.

- Although the number of samples does not provide a firm statistical base, there is some evidence that DDT levels have decreased by a factor of 10 (from 0.2 to 0.026 ppm) in two years. Dieldrin levels showed little or no change compared to those found two years ago. However, we must emphasize that further testing of a larger number of samples would be necessary in order to confirm these results.

- The low levels of DDT, DDE, and dieldrin found suggest that these residues may be due to "steady state" pollution from atmospheric and ocean transport sources rather than residual from previous treatments for vector control.

Need for Action--Research programs on the degradation and metabolism of newer compounds, such as Abate and mineral oils, are needed. Monitoring programs to measure the level of persistent compounds should be expanded and a data bank on the distribution of pesticide residues in the biota of salt water marshes should be developed.

Laws and Regulations

The existing laws and regulations in Massachusetts and some other New England states generally provide a broad and flexible means for controlling pesticides. However, they do not provide adequate environmental protection because little effort is made to assure that actual practices and procedures in the sale, transportation, storage, use and application of pesticides conform to existing laws and regulations. Information distribution, monitoring, investigation, and enforcement are lacking, largely because of insufficient funds, personnel, and facilities. Registration, labeling, and licensing mechanisms are used perfunctorily. They have some informational value, but little control value other than creating a framework inside which incidents and problems can be worked out.

The major reason for this state of affairs is lack of funds for personnel (administrative, legal, technical) and facilities (laboratory, etc.) to control pesticides. Another reason is the lack of coordination between individual state agencies and between state and local agencies concerning their roles in pesticide control activities.

Today, if the public took a close look at the regulation of pesticides in New England, it would find that very little of the authorized regulation is being effectively exercised. As a result, the general public and the environment is mostly at the mercy of the common sense and degree of public interest that persons who use or deal with pesticides voluntarily bring to their work.

This lack of effective control under existing laws and regulations has not escaped notice. There are citizens and groups who have expanded their use of lawsuits, investigations, public accusations, written articles, and political activities to assure that pesticides are more adequately regulated. For example, in Massachusetts, any ten citizens, because of a new law passed in 1971, can bring action in the courts, whether or not they are directly affected by damage or potential damage to the environment. This, and similar actions will likely become more important because citizens have not obtained a prompt, adequate response when they have gone to the existing regulatory agencies in the various states.

If state and local governments do not begin to effectively regulate pesticides soon, these citizen-sponsored lawsuits and other public actions are likely to produce unbalanced solutions for pesticide control issues. There are many legitimate uses of pesticides, including those necessary to provide acceptable control of insect vectors. Some of these uses could be in danger of elimination by side-door solutions based heavily on legal and political criteria. Most pesticide control issues require a great deal of flexibility, accuracy, and delicacy in arriving at balanced decisions. Regulatory agencies, operating properly, can more effectively deal with this broad range of issues in a proper manner.

Alternative Methods of Control

A study of the life cycle of the mosquito indicates that it spends a great deal of time in the aquatic environment, passing through all three juvenile stages (ova, larva, and pupa) in this medium. Most species select small, stagnant pools or puddles of water, which often are contaminated with a great variety of impurities which have run off from surrounding land areas. These impurities present some practical difficulties in developing biological methods of control.

At the present time, the use of mosquito-eating predator fish appears to offer the best overall method of natural control, both in fresh and salt water. In the Southern United States, Gambusia sp. thrive and may live almost exclusively on mosquito larvae. Transplants of these fish have been successful as far north as Ohio, but most efforts to establish them in new England have failed. In the Cape Cod salt marshes there are small salt water fish, such as mummichogs and striped killifish, in small streams and drainage channels. Where these fish are present in large numbers, the population of mosquito larvae in surrounding pools is very low. The problem is to keep these fish in intertidal areas during low tide; as the water retreats, the fish tend to go with it. In certain areas, shallow holes can be dug in the marshes which will retain water even at low tide and provides a sanctuary for the fish. Then, at high tide, the fish are present in large numbers, move out of the holes, and prey on mosquito larvae.

A number of other biological means of control have been described, and some have been proposed for use. The use of disease pathogens has not yet been successful because of the genetic resistance to diseases that mosquitoes have developed while living in contaminated environments. The sterile male technique, whereby artificially sterilized males are released in large numbers to mate with natural females, potentially can be useful in areas where only one or two species of mosquitoes need to be controlled.

Synthetic materials which mimic the action of juvenile hormones have been shown to inhibit pupal development, in laboratory tests and limited field trials. One serious problem to be overcome, however, is the destruction of these compounds by only a few hours of exposure to sunlight.

The most important nonchemical method of controlling salt marsh mosquitoes in New England today is water management by the use of adequately planned and maintained drainage ditches. When coupled with the leveling of small depressions, drainage ditches provide channels for the water to move completely out of the intertidal areas, small pools and puddles are eliminated, and mosquitoes are deprived of preferred places to lay eggs. The ditches must be regularly maintained to avoid silting and debris accumulation which can interfere with the flow of water. In the two salt marshes that we studied on Cape Cod, it is believed that the low use of vectorocides has been made possible by the properly designed and maintained drainage ditches.

While natural controls such as drainage ditches and predaceous fish offer important means of keeping mosquito populations down to acceptable levels, pesticides are required from time to time. The history of vectoricide application to salt marshes in the Cape Cod area indicate that applications may be necessary every year, or not more than once in five years, depending mainly on weather patterns. When mosquito build-ups appear imminent, treatment with a larviciding agent is necessary. When conditions are exceptionally favorable for mosquito growth and reproduction, several applications to the same area may be necessary. For practical purposes, we believe that mosquito populations can be controlled at acceptable levels through the proper and timely use of small quantities of hand-applied larviciding agents.

PART TWO — REPORT AND APPENDIX

I. STATEMENT OF WORK

The objective of this work was to carry out a case study of the pesticides used for insect vector control on Cape Cod in New England, and their effects on the natural environment. An investigation was conducted to provide quantitative documentation of the kinds and quantities of pesticides used, their route from the point of initial application into the water environment, and their ultimate effect on the ecosystems of the Chase Garden Creek section of the Bass Hole Marsh in Dennis, and the Herring River Marsh in Harwich. Further objectives were to analyze the laws and regulations concerning the use of pesticides in New England generally, and for mosquito abatement in Massachusetts particularly, and determine the protection to the natural environment which they provide. Additionally, the importance of non-chemical methods of controlling mosquitoes was investigated.

The major findings of this work, including the needs for action, were summarized in Part One of this report.

II. NATURE AND EXTENT OF VECTOR PROBLEMS

A. DISEASE VECTORS

Two disease problems caused by insect vectors are known in New England, Eastern equine encephalitis (EEE) transmitted by mosquito and Rocky Mountain spotted fever (RMSF) transmitted by the American dog tick. Massachusetts is the only Northeastern state reporting problem areas on both disease vectors.

Approximately 50 human cases of EEE have occurred in the southeastern part of the state in the last 35 years, with a recurrence taking place every ten years.[1] The largest number of human cases--32--were reported in 1936. The disease appeared again in 1946 causing 12 cases, then in 1956 causing six cases, and the last human case was reported in 1970. Before human cases are reported, EEE becomes a serious problem in the equine population. In 1970, although there was only one human case, 54 confirmed equine cases were reported in southeastern Massachusetts. A recurrence of EEE was noted in 1971 with ten confirmed cases of horses reported dead but no incidents reported on humans.

The second disease problem, Rocky Mountain spotted fever spread by the American dog tick, also is known only in the southeastern part of Massachusetts. Nearly all cases--which have been reported at an average rate of one a year for the last 30 years--occurred in the Cape Cod area.

Scattered cases of EEE and RMSF are reported from time to time in the Boston area or inland, but their origins have all been traced back to the southeastern part of the state.

[1] Private communication with Dr. Waterman, Department of Public Health, Commonwealth of Massachusetts, Boston, Massachusetts.

Neither Rhode Island, New Hampshire nor Maine have reported any major problem area of disease vectors. New Hampshire and Maine consider that the southeastern parts of their states have a potential for disease vector problems because of the proximity to Massachusetts, but cases have not been reported.

Vermont has had cases of tularemia transmitted by deer flies, and a total of 30 human cases have been reported over the years to the Vermont Pesticide Advisory Council with a 10% mortality incidence. Outbreaks of other diseases caused by vectors have not been reported.

B. NUISANCE VECTORS

Vectors are considered a nuisance problem throughout New England. The mosquito population, although spread throughout the area, causes greater problems in the coastal areas due to salt marshes and a large number of ponds. The nuisance is also more severe along the coast because population and summer resorts are concentrated more heavily in that area. Like mosquitoes, black flies are a nuisance problem throughout the region, but only a few control programs have been established.

In addition to mosquitoes and black flies, green flies are reportedly a nuisance in the state of New Hampshire, especially in the mountain area. Green head flies and culicoids are reportedly a nuisance problem along the coastal areas of Massachusetts.

Maine reports nuisance mosquito, black fly, and deer fly problems, but only mosquitoes and black flies receive treatment. There are no organized treatment areas, and most work is done privately around lakes and ponds, drive-in theaters in low-lying areas, and homeowner fogging.

III. PESTICIDES USED FOR VECTOR CONTROL

A. KINDS OF MATERIALS USED

Probably the first method of chemical control of mosquitoes consisted of the spreading of petroleum oil over standing water on the marsh lands. The oil killed the larvae by eliminating oxygen at the water surface. Chemical products can be used either to eliminate the insect at a larval stage (larviciding) or to eliminate it in the adult stage (adulticiding). Under most conditions, control procedures against mosquitoes are most effective and most economical when designed to eliminate larvae. Mosquito larvae live only in water, and the management of water is the basic means of control, but often it must be complemented by pesticides, chemicals, or oils, known as larvicides. In areas where stagnant water contains only one brood of mosquito larvae, one well-timed application of a suitable pesticide in the spring may be all that is necessary. Where several broods are present, a pesticide application for each brood may be required.

Today, many different materials are used as larvicides, including mineral oils (such as Flit MLO), Abate, malathion in oil, and others. The oils provide effective control by killing mosquitoes in all their aquatic stages--ova, larva, and pupa. The oil on the water surface has a lasting time of 48 to 72 hours. Kill may be rapid when water is calm, but slower and less positive with wave action and wind. In some cases, the larvae may live but appear to be in suspended animation, and control crews have elected to re-treat with chemical pesticides. Control of adult mosquito populations is done primarily by chemical methods. The control is mostly temporary and the effectiveness depends not only on the thoroughness of the control methods, but also on the size of the area treated, the species, and the life stages. Since some adult mosquitoes may fly several miles, adulticiding programs must cover a large area. These insects migrate so far and so quickly that an individual cannot obtain any measurable relief by his own efforts, and entire areas must be treated.

In chemical control there are at least two types of treatments: in one, the insects are killed almost instantly after application, by contact with the insecticide which has a high acute toxicity; in the other, long-lasting components have a residual effect. With proper timing and thorough coverage, an adult mosquito population can be reduced to acceptable levels quickly with materials such as malathion and naled. On the other hand, treatment with methoxychlor may result in less rapid but longer lasting control since it does not degrade as quickly as the phosphates.

In the case of other nuisance insects in New England, such as the green head fly, chemical control (when used) is applied mostly to the adult population. Larval control is difficult because the breeding cycles are not well known and breeding sites have not been adequately described. When chemicals are used for green head fly control, malathion is popular. On Cape Cod, nonchemical methods such as the Manitoba boxes (cages) appear to provide some relief by trapping females.

B. SPECIFIC MATERIALS USED

Until its application was banned, DDT was the most popular pesticide used for vector control in New England, but in 1970 only the states of Maine and Vermont reported its use. Malathion, naled and methoxychlor are currently the most popular pesticides used to control the adult mosquito population. Mineral oils, Abate, methoxychlor and malathion in oil are the most popular larvicides.

C. QUANTITIES USED

Shown in Table III-1 is the estimated total pesticide consumption within each state in New England. These estimates, from the New England Governor's Conference, are not based on exhaustive surveys, but rather on the records kept in recent years by agencies in some states and personal knowledge and experience of officials in other states. Available data on the types and quantities of pesticides used in New England for mosquito control is largely incomplete. For the most part it represents only that portion of the control program that falls within the jurisdiction of a local or state agency. Some states can estimate the quantities from reports required of custom applicators, but others have not yet established sufficiently good record-keeping systems.

The state of New Hampshire requires that all pesticide applicators be registered with the Pesticide Board, including government agencies, and make an annual report of the types and amount of pesticide used annually. It is the only one in the New England region that can provide state-wide information on the materials used for vector control. In the other states where individual or community efforts are not required to report to the state's pesticide office, no records are kept that will permit extracting comprehensive data as to the types and amounts of pesticides used.

TABLE III-1

ESTIMATED CONSUMPTION OF PESTICIDES IN NEW ENGLAND, 1969

(thousands of pounds active ingredient)

Kind	Connecticut	Maine	Massachusetts	New Hampshire	Rhode Island	Vermont
Farm & Commercial Insecticides						
Malathion	20.5	102.0	N.A.	5.7	4.2	N.A.
Methoxychlor	N.A.	22.0	N.A.	N.A.	N.A.	N.A.
Carbaryl	39.7	83.0	N.A.	10.3	12.1	N.A.
DDT	9.2	1.0	N.A.	12.6	11.8	N.A.
Chlordane	26.5	N.A.	N.A.	4.5	2.1	N.A.
Others	68.3	1636.0	N.A.	48.9	—	—
Sub-Total	164.2	1844.0	1206.4	82.0	N.A.	N.A.
Herbicides	51.2	267.0	523.7	38.4	N.A.	N.A.
Fungicides	7.9	2610.0	963.8	74.5	N.A.	N.A.
Total	546.7	4721.0	2693.8	194.9	37.5	160.0
Household	1243.0	543.0	1554.0	202.0	259.0	121.0
Grand Total	1789.7	5264.0	4247.8	396.9	296.5	281.0

N.A. = Not available

Source: "Report on Use and Control of Pesticides in New England," The New England Governor's Conference Committee on Environment, July 7, 1971.

Table III-2 presents partial information on the products used by the individual states. This data is subject to the following comments:

- New Hampshire has records of most of the pesticides used in the state for vector control because the state requires that all applications of pesticide made by licensed persons to the land of another be recorded and records made available. The Board of Pesticides keeps yearly records (since the time of its formation) of the types and quantities of pesticides used in the state. Data prepared by the Board for this study excludes applications made to private lands by owners.

- Massachusetts statistics represent the estimated pesticide requirements for vector control as submitted by the eight individual Mosquito Abatement Districts to the State Reclamation Board. Since these requirements are estimated substantially in advance of use, there may be differences in the final use pattern. Data does not include products used by municipalities, communities and individual applicators, and no record in this respect is maintained at the state level.

- Maine data reported by the State Board of Pesticide Control represents only partial information since the regulation establishing required reporting of pesticide usage by custom applicators was enforced only during 1970.

TABLE III-2

ESTIMATED CONSUMPTION OF PESTICIDES FOR MOSQUITO CONTROL IN NEW ENGLAND

Chemicals	New Hampshire			Massachusetts			Maine			Connecticut		
(lbs. Active Ingredients)	1970	1969	1968	1970	1969	1968	1970	1969	1968	1970	1969	1968
Malathion	4,100	4,100	4,100	32,000	26,315		410			550	550	
Methoxychlor	3,804	3,800	3,800	10,550	19,236		420					
Carbaryl	2,626	2,600	2,600									
Abate				3,100	11,215							
Carbofuran				140	42							
Naled				4,430	2,180		152					
Fenthion				1,000	1,624		5			160	160	
DDT		1,000	1,000				37					
Total	10,530	11,500	11,500	51,220	60,612		1,074			710	710	
Mineral Oil (gal.)				7,000			600					

Sources: Connecticut State Department of Health
Maine State Board of Pesticide Control
Massachusetts State Reclamation Board
New Hampshire Pesticide Control Board
Rhode Island Department of Natural Resources--no data available
Vermont Pesticide Advisory Council--no data available

- Connecticut data refers to pesticides used by the state to control salt marsh mosquito species along the shore, and does not include pesticides used for freshwater mosquito control. Inland control is left to the individual cities and towns for solution and records are not available at the state level. To obtain accurate and complete information would require contacting 169 towns in the state, first by letter and then by follow-up visit.

- Vermont: No figures exist on the actual use of pesticides in Vermont, although estimates have been made by state officials. In a report to the Governor, the Vermont Pesticide Advisory Council stated that there are no state laws governing the use of pesticides by public and private agencies or individuals and records of pesticide use in Vermont are incomplete and preclude meaningful assessment.

- It is believed that relatively little amount of chemical pesticides have been used in Vermont, compared with the previous decade. The only known record of pesticide use for vector control is for DDT in 1967, when 600 pounds was delivered to local associations and custom applicators (ground equipment) for use in mosquito and shade tree spraying in the Burlington, St. Albans, and Grand Island areas. As of December 1971, however, usage of DDT will be banned in the state. New measures concerning licensing of custom applicators by the Pesticide Advisory Council will improve procedures for record-keeping of pesticide application throughout the state of Vermont.

D. PESTICIDES USED ON CAPE COD

Kinds and quantities of pesticides used for vector control on Cape Cod by the Cape Cod Mosquito Control Project are shown in Table III-3. As reported by the Cape Cod Mosquito Control Project, the official abatement district for Barnstable County, fuel oil has been the principal material used over the years. Chemical pesticides were used after World War II, when the effectiveness of DDT was shown. However, concern over possible residue build-up, together with signs of insect resistance to DDT, resulted in a shift to other materials.

Dieldrin was used for about five years but was replaced with Abate (an organophosphate) and Paris Green (copper acetoarsenite). These materials were in turn followed by malathion for the salt marshes, and DDT for the freshwater swamps which offered no outlet to salt water and no route to estuaries. In 1969 and 1970, these materials were given up in favor of a new mineral larvicide oil formulated especially for mosquito larva control.

E. PESTICIDES USED IN TWO SALT MARSHES

Shown in Table III-4 are the kinds and quantities of pesticides used in the Bass Hole Marsh in Dennis and the Herring River Marsh in Harwich for the years 1961-1971. The data, as supplied by the Cape Cod

TABLE III-3

MOSQUITO LARVICIDES USED ON CAPE COD, 1930-1971

Period	Material	Final Formulation	Quantity (Active Ingredients)
1930-1942	Fuel Oil	-	Not recorded
1930-1942	Pyrethrums	Various	Test quantities only
1945-1956	DDT	6.25% in fuel oil	2500 lbs. per year
1957-1961	Fuel Oil	Surfactant 1:400	4000 gals. per year
1957-1961	Dieldrin	2% granular	200 lbs. per year
1962-1965	Abate	2-1/2 oz. in 50 gal. water	160 lbs. per year
1962-1965	Paris Green	10% granular	800 lbs. per year
1966-1969	DDT	10% granular	400 lbs. per year
1966-1969	Malathion	2% in fuel oil	250 lbs. per year
1970-1971	Larvicide Oil	As received	3000 gals. per year

Source: "History of the Cape Cod Mosquito Control Project, 1928 to 1971"

TABLE III-4

PESTICIDES USED FOR MOSQUITO CONTROL IN TWO CAPE COD MARSHES, 1961-1971

(Active Ingredient Basis)

Year	Fuel Oil Plus Surfactant (gal.)		Abate (lbs.)		Malathion (lbs.)		Larviciding Oil (gal.)	
	Bass Hole	Herring River	Bass Hole	Herring River	Bass Hole	Herring River	Bass Hole	Herring River
1961	36.0	6.0						
1962		21.0						
1963		9.5						
1964		10.5						
1965	44.5	6.0				0.17		
1966	3.0		0.03	0.01	2.76	1.21		
1967					15.52	3.28		
1968					13.45	1.38		
1969			0.19	0.15				
1970				0.01	2.03	1.55	18.0	8.0
1971							11.5	4.0

Note: Bass Hole Marsh includes Chase Garden Creek and tributaries.
Herring River Marsh (West Harwich) between Bells Neck and Lothrop Roads.

Source: From data supplied by the Cape Cod Mosquito Control Project.

Mosquito Control Project, shows malathion to be the most important chemical used during this period, but oils made up the largest total quantity. A shift from oil to chemical back to oil is noted, reflecting dissatisfaction with the chemicals.

IV. METHODS OF APPLICATION AND TYPES OF MATERIALS USED

There are two general types of pesticide applications used for mosquito control in New England: larviciding and adulticiding. Each can be done mechanically or by hand, but in general, adulticiding is done both by machine and by hand.

A. ADULTICIDING

The modern control of adult mosquitoes is most successfully carried out by aerosols, using ultra-low volume, thermal and non-thermal equipment. Both ground and aerial equipment are used in New England. The popularity of this type of application focuses around:

- The speed with which large areas can be covered with well-dispersed aerosols.
- The small quantities of material and diluent needed reduces the number of refills and speeds up the operation.
- The control of droplet sizes provides flexibility in confining applications to the target areas.

Indiscriminate use of aerosol equipment could provide a route of pesticides into the water environment. There is a danger of introducing chemicals accidentally into live streams when large areas are covered. Variations in wind speed or direction, and variable temperature gradients between different elevations can mean trouble for careless operators who do not adjust their machines accordingly. Aerosols which are allowed to drift out of the target areas are a major source of concern to regulatory agencies, and account for a sizable number of complaints from property owners and inhabitants.

The use of high-volume equipment has been reduced in New England, and most mosquito control programs use other means. There are, however, several cities and towns that still use hydraulic machines to cover large trees with ground equipment. The large volumes used (up to 100 gallons or more per acre) may cause drip and runoff problems, particularly in urban areas where paved streets, sidewalks, parking lots, etc., cut down on the area of soil available to absorb and degrade these materials.

B. LARVICIDING

In our study area all larviciding has been done by hand using back-pack sprayers. With this equipment, precise applications of larvicides can be made that will reduce or eliminate the entry of materials into the water environment. Spot treatments of stagnant pools and puddles can be made, and wasting chemicals on other areas is avoided. There are obvious savings in materials, although there are also high labor costs.

Mechanical larviciding is done with low-volume, liquid aerial or ground equipment, and with broadcast spreaders of granular materials. Indiscriminate use of mechanical larviciding, like adulticiding, can place pesticides where they can be transported into water. Equipment used to spread liquid larvicides include standard low-volume machines which can apply in the range of 5-10 gallons per acre. Helicopter-mounted booms and nozzles can be calibrated at these rates. Ground equipment may be the same as used for aerosols, but adjusted to provide larger quantities of larger droplets.

Granular broadcasters, aerial or ground, consist normally of a spinning disk which imparts centrifugal force to each granule and moves it a measured distance from the machine. Particle size, disk speed, and forward speed of the carrying vehicle all can be varied to change the rate of application. Normal rates are in the range of 10-20 pounds per acre of formulated materials.

C. FORMULATIONS OF MATERIALS USED

1. Larvicides

In New England, the major material used in 1970 for larvae control was malathion, and the major formulation was 2% active ingredient dissolved in fuel oil. Starting material is usually 55-57% emulsifiable concentrate containing about 5 pounds malathion per gallon. Standard No. 2 fuel oil is the major diluent, and surfactants (spreader-stickers) may or may not be necessary depending on the concentrate used.

Abate, an organophosphate compound produced specifically for larviciding, is normally used in a water solution at the rate of 5-10 gallons per acre. The emulsifiable concentrate tests about 49% and contains 4 pounds Abate per gallon. Working solution is made by dissolving 5 fluid ounces of the concentrate in 50 gallons of water.

Mineral oils especially refined for mosquito larviciding (such as Flit MLO) are normally applied in the same form as received, and not diluted. Analyses indicate contents of 99% petroleum fractions and 1% inert ingredients. It is widely believed that the inert fraction may consist of surfactants.

2. Adulticides

The use of ultra-low volume applicators has brought about a change in materials used to kill flying, adult mosquitoes. Special formulations of concentrated products are now used widely throughout New England, the most popular being malathion (95%, 9.7 lbs. active per gallon) and naled (85%, 14 lbs. active per gallon).

When applied in accordance with label instructions, ULV concentrates differ very little from normal emulsifiable concentrates of lower dilutions. In these highly concentrated forms, however, they are more dangerous to handle during transportation and applicator loading. Accidental spills can release them into the environment where they would pose a threat to nontarget organisms. Accordingly, a greater burden is placed on the application supervisor, who must ensure that his operators have received proper timing and have proper respect for the material.

D. FORMULATIONS OF PESTICIDES USED ON CAPE COD

Early pesticides used on Cape Cod to control mosquito larvae consisted of fuel oil only. Various formulations of pyrethrums were used in early years, but sufficient records are not available to define exact formulations. From 1945 to 1956, the Cape Cod Mosquito Control Project reports that the DDT it used was formulated with 75 pounds technical DDT (about 99% pure), 10 gallons of Xylene, and 140 gallons of fuel oil. Application was at the rate of 5-10 gallons per acre. Dieldrin as 2% granular served as the pre-season larvicide from 1957 to 1961, at the rate of 10-12 pounds per acre in freshwater swamps, with about one-fourth of the total area covered. Fuel oil fortified with one pint surfactant to

50 gallons was used during the season. Paris Green granules, 10% active, were used in 1961-1965, together with a solution of Abate consisting of 5 fluid ounces of 49.2% Abate 4E (contains 4 lbs. active per gallon) in 50 gallons of water. The low quantities applied shown earlier in Table III-4 are based on a general application rate of 10 gallons per acre of this dilute solution.

When the use of DDT was restarted in 1966, the 10% granular form was applied to freshwater mosquito breeding areas. On the average, about 0.1 lb. active DDT was applied to each acre. Malathion was used from 1966 to 1970, in an oil solution formulated with 3-1/2 gallons of 57% emulsifiable concentrate (5 pounds active per gallon) in 100 gallons of fuel oil.

The pesticides used in Bass Hole and Herring River Marshes were based on the above formulations.

V. ROUTE OF PESTICIDES INTO THE WATER ENVIRONMENT

A. INTRODUCTION

The route of pesticides into the water environment has been categorized broadly as either (1) intentional or (2) accidental. These routes have been further subcategorized[1] as follows:

(1) Intentional

- (a) Agricultural and forestry uses;
- (b) Aquatic uses for controlling insects, weeds, trash, fish, etc.;
- (c) Household and garden use;
- (d) Municipal and industrial use;
- (e) Public health use;
- (f) Manufacturing.

(2) Accidental

- (a) Accidents in manufacture, handling, transportation, storage and use;
- (b) Industrial and municipal wastes;
- (c) Agricultural wastes such as crop residues, food, industrial wastes;
- (d) Drift from application or movement by attachment to soil particles, etc.;
- (e) Fires, floods.

To varying degrees, all of these represent potential routes of pesticides used for vector control into the environment of the New England States. Because of the objectives of vector control some paths of pesticides into the water environment are, obviously, of much less importance than others; for example, accidental releases during manufacturing, handling, transportation, storage and use could be expected to be less contributory than would intentional application near aquatic areas for public health use. Nevertheless, accidental releases would be expected to have a greater immediate impact on a localized environment due solely to concentration effects than the intentional releases which would be contributory to chronic background levels over long terms. Because pesticides for vector control may require several handling and transfer operations before their final, intentional application, our examination of their routes into the water environment began with tracing their paths from the manufacturing plant through the distribution channels to the final application points in order to assess all potential routes for entry into the water environment.

B. HANDLING AND TRANSFER METHODS

The products used in vector control in New England, especially in the Cape Cod area which is of particular concern to us, basically are not manufactured in the region, although some formulation may take place. Consequently, the potential entry into the water environment at manufacturing sites is of limited concern in this region. Nevertheless, the prevention and control of spills of hazardous polluting substances[2,3] demands increasing attention at all stages of formulation, storage, transfer, transportation and distribution. A number of surveys[3,4] have indicated that the loading, transportation and unloading operations are areas of high potential for spills; furthermore, there are areas where inadequate provisions often exist for preventing or controlling the spread of spilled substances.

In New England the pesticides products used in vector control are shipped into the region by trucks and rail transport. Tank cars and tank trucks are used when large volume usages justify the economics of such transportation. The most frequent methods of shipment are in five-gallon cans or fifty-five-gallon drums for liquid products and plastic-coated paper bags for solid products. Truck transport can be either in company or hired carriers. In the case of less than truckload shipments, company trucks most commonly ship pesticides with other hazardous polluting substances, e.g., oils. In the case of hired carriers' transporting mixed cargoes, there is no direct control over the product mix being shipped.

Accidental spillage or leakage of pesticides during shipment such as might occur in truck or rail accidents, can be reported by the operators to the Pesticides Safety Team Network in order to obtain advice and assistance in prompt and effective cleanup and decontamination. This network became operational on March 9, 1970, when a central telephone number (513) 961-4300 in Cincinnati, Ohio, was activated on a 24-hour basis. Twelve member companies of the National Agricultural Chemical Association (NACA) are cooperating in the program by furnishing personnel, equipment, and expertise for the prompt and efficient cleanup and decontamination of Class B poison pesticides involved in a major accident. More than forty safety teams currently make up the national network, the operation of which is outlined in the attached "Emergency Procedure for Handling Accidental Spills of Class B Poison Pesticide Chemicals." The success of the network depends principally on (1) the rapid notification of such an accident by someone at the scene and (2) the rapidity with which isolation and containment of the spills is achieved so that cleanup and decontamination can proceed effectively.[5,6] The Safety Team Network has a voluntary cooperative agreement with the American Truckers Association (ATA). There are, however, no laws or regulations to enforce notification of such accidents, and incidents have occurred where drivers were unable or unprepared to hold trucks until the Safety Team Network had the opportunity to inspect the site and take appropriate action. Although our survey did not discover any reported transaction incidents, it seems very clear that the potential for massive entry of pesticides into the water environment is very high during transportation because of the volumes involved and the difficulties of preventing migration into water resources.

The shipping destination from the manufacturer's plant or central distributing warehouse (in some cases, carg [illegible] temporarily stored at trucker's terminals) is one or more of th [illegible] ing points:

(a) Wholesaler or loca [illegible] butor

(b) Vector control dist [illegible]

(c) City, town or municipality

(d) Commercial applicators

(e) Retailers

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When the products are received at (a) they are stored for further transfer to another destination such as (b), (c), (d), or [illegible]. In the case of large volume users such as vector control districts and commercial applicators, shipment may be direct from the manufacturer. Our contacts with distributors did not uncover any admissions of losses due to breakage or leakage from cans, drums or bags. The explanation given most frequently was that the present high cost of pesticides resulted in better packaging in small units (5-gallon cans or 4-pound bags) to allow easier handling. Furthermore, the containers themselves are more resistant to breakage than was the case with low-cost products, e.g., DDT, where the low competitive prices for the product precluded quality packaging. The results of our survey indicated that the probability for entry of massive amounts of pesticides into the water environment during their transportation from manufacturer to wholesale distributor are no greater than any other hazardous polluting substance being transported in commerce.

C. FINAL APPLICATION AND CONTAINER DISPOSAL

Once the pesticide has reached the organization or person responsible for its final dispersal, its application and the disposal of containers is to a large extent determined by the laws and regulations of individual states. While applicators are primarily responsible for intentional additions of pesticides to the environment, they must also be considered for potential releases due to accidents in handling, preparing and applying pesticides as well as the disposal of used containers, unused products and equipment cleaning solutions. Our survey of pesticide applicators indicated that recently issued regulations, which are more stringent than older rules, are resulting in fewer but more proficient applicators; those without broad knowledge of pesticides and their uses often discontinue operations. For example, we estimate that within recent years nearly 20% of New Hampshire's applicators have left the business, primarily those not attuned to the broader aspects of pesticides as applied to vector control. This indicates a trend toward upgrading the quality of commercial applicators, a very desirable step forward in assuring better usage of pesticides.

During our field interviews we encountered difficulty in getting straightforward answers to many of our questions regarding the procedures for disposing of used containers, unused pesticides, and equipment cleaning solutions. Although the states of Massachusetts, New Hampshire and Maine have established specific regulations concerning the disposal of containers on unused pesticides (see Table V-1 for a summary of these regulations), we could not confirm that these regulations are strictly observed by the applicators or closely monitored by state regulatory agencies. We received reports in Massachusetts that pesticide bags as well as crushed containers and drums often are disposed of at town dumps, but we could not determine whether these areas are officially designated by local Boards of Health for disposal as required by Massachusetts law. Several commercial pesticide applicators complained that many towns had no such areas, and any disposal would be in technical violation. Burning of combustible containers, and dilute solutions of pesticides in combustible solvents, in municipal incinerators or other devices approved by the Board of Health is prescribed in Massachusetts, Rhode Island and New Hampshire; however, we found no indication of the relative frequency of incineration as compared with burying. Furthermore, we were able to obtain only meager information concerning the actual methods of disposing of equipment and container washings. Although the rules and regulations in New Hampshire and Rhode Island are quite clear in the procedures to be used, other states generally specify only that these shall be disposed of by burial in a manner which will prevent entry into the water environment.

TABLE V-1

REGULATIONS IN NEW ENGLAND STATES CONCERNING DISPOSAL OF UNUSED PESTICIDES AND EMPTY CONTAINERS

	MASSACHUSETTS	NEW HAMPSHIRE	MAINE	VERMONT	CONNECTICUT	RHODE ISLAND
1. **Disposal Areas**	Municipal incinerator or other place assigned by the local Board of Health	Municipal incinerator or approved disposal site	Stored in a safe place or buried: (1) on the land of the applicator or (2) on the land of and with the approval of other than the applicator provided that in no case is such material to be put in or close to watering wells, open springs or areas where material will flow directly into waterings.	THE DISPOSAL OF SURPLUS AND OBSOLETE PESTICIDES AND USED PESTICIDE CONTAINERS IS NOT SPECIFICALLY PROVIDED FOR UNDER ANY STATE REGULATIONS.	Disposal in public sewage systems is prohibited. No pesticide or container therefore shall be discarded in such a manner as to cause pollution of any waterway or endanger plant and animal life or the public health and safety.	Containers are to be disposed of only at approved refuse disposal sites, in a municipal incinerator or in a special incinerator which meets with the approval of the Department of Natural Resources.
2. **Disposal Method** 2a **General Provisions**	In such a manner and at such location that contamination of ground or surface water is minimized and that the material will not be uncovered or otherwise disturbed during subsequent operations in the area. If buried, pesticide shall be covered with at least 18" of compact cover material.	Surplus or unused pesticide shall be disposed of by burial in same manner as Massachusetts.	Buried with at least 18" of compacted cover material.		THE DISPOSAL OF SURPLUS AND OBSOLETE PESTICIDES AND USED PESTICIDE CONTAINERS IS NOT SPECIFICALLY PROVIDED FOR UNDER ANY STATE REGULATIONS.	Excess or unused pesticides shall be disposed of by burial with at least 18 inches of compacted cover in such a manner and at such a location within the disposal area that contamination of ground water is prevented.
2b **Liquid Combustible**	Other than organophosphate and hormone type may be burned and residues disposed according to 2a. Burning is restricted to 2 days a week and 1 gallon per time under appropriate atmospheric conditions. Organophosphate and hormone types treated as non-combustible.					

TABLE V-1 (Continued)

	MASSACHUSETTS	NEW HAMPSHIRE	MAINE	VERMONT	CONNECTICUT	RHODE ISLAND
2b (continued) Non-combustible	By burial in accordance with 2(a)					
2c Solid	By burial in accordance with 2(a)					
2d Containers	According to rules and regulations established by the Dept. of Public Health.	NON-COMBUSTIBLE CONTAINERS USED IN CONNECTION WITH ORGANOPHOSPHATE COMPOUNDS: Glass: breakage and burial (18" deep) Metal: rinsing, punching holes on top and bottom, crushing and burning. Rinsing solution should be buried OTHER THAN THOSE USED IN CONNECTION WITH ORGANOPHOSPHATE COMPOUNDS: Rinsing and disposing of water by burial	If not returnable, shall be perforated or crushed and buried with at least 18" of compacted cover material.			Organophosphate Containers Glass - Break and bury as in 2(a). Metals - Wash with caustic soda and detergent solution. Bury rinse water as in 2(a). Other Pesticide Containers Rinse at least twice with suitable solvent. Dispose of rinses as in 2(a). One-gallon cans are to be punctured and buried as in 2(a).
3. RE-USE of Containers	Unless treated in conformity with Public Health regulations, containers shall not be used for storage of human or animal food or water or for the storage of cooking utensils, dishes or clothing.	No pesticide container shall be used for storage of food, water, cooking utensils, dishes or clothing. No pesticide containers should be used for any other purpose unless approved by the Board of Health after properly cleaned.	Return to manufacturer if returnable, or sell to reconditioning companies. All other containers shall be handled in accordance with 2d.			No pesticide container shall be used for the storage of human or animal food or water nor such containers be used for the storage of cooking utensils, dishes or clothing. No pesticide containers shall be used as dock or raft floats. No other purpose unless such purpose has been approved by the Department of Natural Resources after the containers have been properly cleaned.

Other potential paths for entry of pesticides into the water environment are through back-siphoning when tanks are filled from surface waters and where inattention results in overflow of tanks. The practice of siphoning water from surface supplies is forbidden in New Hampshire--an excellent precautionary measure in our opinion.

In summary, although we have not yet documented specific incidents where pesticides entered the water environment due to accidents or poor disposal practices by the applicators, we also were unable to ascertain any uniformity of control practices by regulatory agencies. Because of the multiple handling, mixing, and transfer required of the applicators, there is a potential for significant numbers of uncontrolled entries into the water environment.

In our opinion, better procedures should be developed to help reduce the potential for spills such as requiring all loading and unloading of concentrated liquid pesticides be performed on impervious surfaces in a curved area draining to a containment sump from which spilled materials could be removed and treated for disposal. The disposal of spent containers and unused pesticides should be monitored more closely, perhaps through an accountability system such as numbering of containers and requiring return to an authorized disposal site and specific disposal procedures established for each pesticide. Although a number of legalistic schemes might be developed for reducing the potential for spilled pesticides getting into the water environment, the most desirable first step is an expanded educational program involving the applicators including, perhaps, a licensed operators program such as employed for sewage treatment plant personnel.

D. INTENTIONAL APPLICATIONS

The intentional application of pesticides for vector control in the Northeastern United States utilizes all of the commonly accepted methods of air, ground and water application. Atomization of liquids for application from air or ground-borne equipment has been the subject of large numbers of studies to determine the most desirable droplet size ranges and atmospheric conditions. These are two prime factors in affecting the distribution of active materials, and minimize the drift of particulates into unwanted areas. Akesson, et al.[7] gave a succinct review of methods for controlling spray atomization in aerial applications. Both air and water routes of pesticides dispersion in the environment is discussed in the January 1969 "Report to the President--Control of Agricultural Related Pollution." Aerial application or ground application using foggers are the most difficult to control precisely with respect to area covered. Both methods could, conceivably, cause direct entry of pesticides into the water environment, but only where direct spraying is carried out or where drift occurs. In the Cape Cod area there are cranberry bogs which may inject pesticides into "flooding" water, but provisions are made to hold the water sufficiently long enough for deposition and degradation to occur, before drainage to water courses is allowed. Of course, the holding time required for complete degradation may be impossible in the case of some pesticides; consequently, adsorption on soil particles and detritus with concomitant slow release rates must be relied upon to minimize widespread dispersion throughout the ecosphere.

The air route of pesticide application is dependent, obviously, on the microclimatology effects at the site of application. Although elaborate mathematical models[8] exist for predicting the dispersion of aerosol from point and diffuse sources, the major criteria for the application of pesticides is that calm wind conditions prevail and that temperature gradients meet certain criteria. It is generally accepted[9] that a normal lapse condition (i.e., where temperature decreases with height) of about 0.1°F should exist between the 8 and 32 foot elevations. The effect of wind velocity on horizontal drift of an aerosol particle of a given diameter is to increase the drift distance in virtually direct proportion to the wind velocity. Consequently, careful consideration[11] must be given to the optimum droplet size as well as atmospheric conditions for effective, safe application.

In our surveys of the Cape Cod area we determined that ground and helicopter spraying equipment is more common than fixed wing aircraft. The use of helicopters is attributed primarily to the limited field size, the wooded nature of the terrain, and the nearby location of a U.S. Air Force Base. The direct application of pesticides onto water is practiced only on cranberry bogs, where the technique of holdup of the water for a specified period of time is practiced.

The generally sandy nature of the soils in the Cape Cod area could be expected to have a lower adsorptive capacity than clayey soils[11] or, conversely a higher release rate by either desorption or, in the case of the more volatile pesticides, by volatilization.[12] Furthermore, only the most persistent pesticides or their metabolites might be expected to be found in the soil column at any appreciable depth. For example, we were told[13] that where chlordane has been applied to golf courses on Cape Cod for control of Japanese beetles, chlordane content four inches beneath the surface is in the range of 0.05 to 0.08 ppm and estimates of deepest penetration are in the vicinity of three feet. Literature references[1] describe laboratory studies which indicate that the transmigration rates of such refractory pesticides as dieldrin may be extremely slow and in extreme cases, as long as several hundred years per foot of soil. Obviously, no generalization can be made because the adsorptive-desorptive properties are so highly dependent upon the individual pesticide, its degradability and the unique properties of the soil into which it is dispersed. Therefore, the most pertinent information must rely upon analyses of samples recently secured from the area and these are discussed in another section.

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VI. IMPACT ON THE ENVIRONMENT

A. DESCRIPTION OF STUDY AREA

1. Geographic and Hydrologic

Salt water marshes are land forms resulting from the invasion of shallow water by land vegetation. They develop in those coastal areas where land erosion and deposition of sediments have built up an intertidal flat and where the shore is protected from the open sea by a bay or spit. On Cape Cod, as along the entire glaciated East Coast, the marshes formed on land scraped bare by the retreating ice, or on piles of debris left as the glaciers melted. *Spartina alterniflora* grass germinated in these areas anchoring the soil and preventing further erosion. Once established, such salt water cordgrass built up the marsh by accumulating salt marsh peat and by acting as a trap for sediments brought seaward or carried shoreward by the incoming tide.[1]

Each successive generation of marsh grass grows on the root stocks and trapped sediments of the preceding generation causing the marsh to increase in depth and to spread. At the same time, the deposition of sediment continues, primarily by incoming tides, but also from inland runoff carrying silt from the land, allowing cordgrass to become established further out into the intertidal flats. On Cape Cod the Sandwich moraine stretches from the Cape Cod Canal to Orleans at a height of 100 to 300 feet above sea level. This mass of sand, clay and rock cleanly separates our two study areas and the Bass Hole Marsh and Herring River Marsh receive entirely distinct runoff water, although the two areas are within six miles of each other.

The entire area has exceptionally good drainage and the soil a high infiltration rate; rain water percolates through the sandy/gravely soil rather than running off. The major difference between these two Cape Cod marshes and most other salt water marshes is the low volume of fresh water and inland nutrients resulting from runoff.

The moraine is largely uninhabited, and there is little waste to the Bass Hole and Herring River Marshes; waste from areas of dense population in general passes directly into Cape Cod Bay on the north or Nantucket Sound on the south. Because of this pattern these two marshes are largely uncontaminated by industrial pollutants and domestic sewage. Agricultural wastes are little in evidence; the major segments of Cape Cod agriculture have declined, and only a few active cranberry bogs and nurseries remain.[2] In general, although there has been an increasing population pressure on Cape Cod, little ecological change has resulted from the increased release of wastes and marshes have generally retained their form.

The marshes under study are unusual in that the effect of surf is negligible. The Herring River effectively separates its marsh from the sea, and a large permanent sand bay isolates Bass Hole.[3] Water mixing in these marshes is therefore almost entirely the result of tidal action and density inversions.

The Herring River Marsh water system does interconnect with fresh water ponds upstream of the area we studied. The Bass Hole Marsh area studied, in contrast, has no contact with open bodies of fresh water. There is a significant difference in the magnitude of the tides; in the Bass Hole Marsh the mean range is approximately 9.5 feet, while at the mouth of the Herring River there is a mean range of 3.7 feet.

Water temperature also was another physical characteristic which has an effect on the biota of the two marshes. Cape Cod Bay at the mouth of the Bass Hole Marsh is cooled by the Arctic Current, but an extensive sand bar allows little cold water to enter the area. In contrast, Nantucket Sound is warmed by the Gulf Stream.

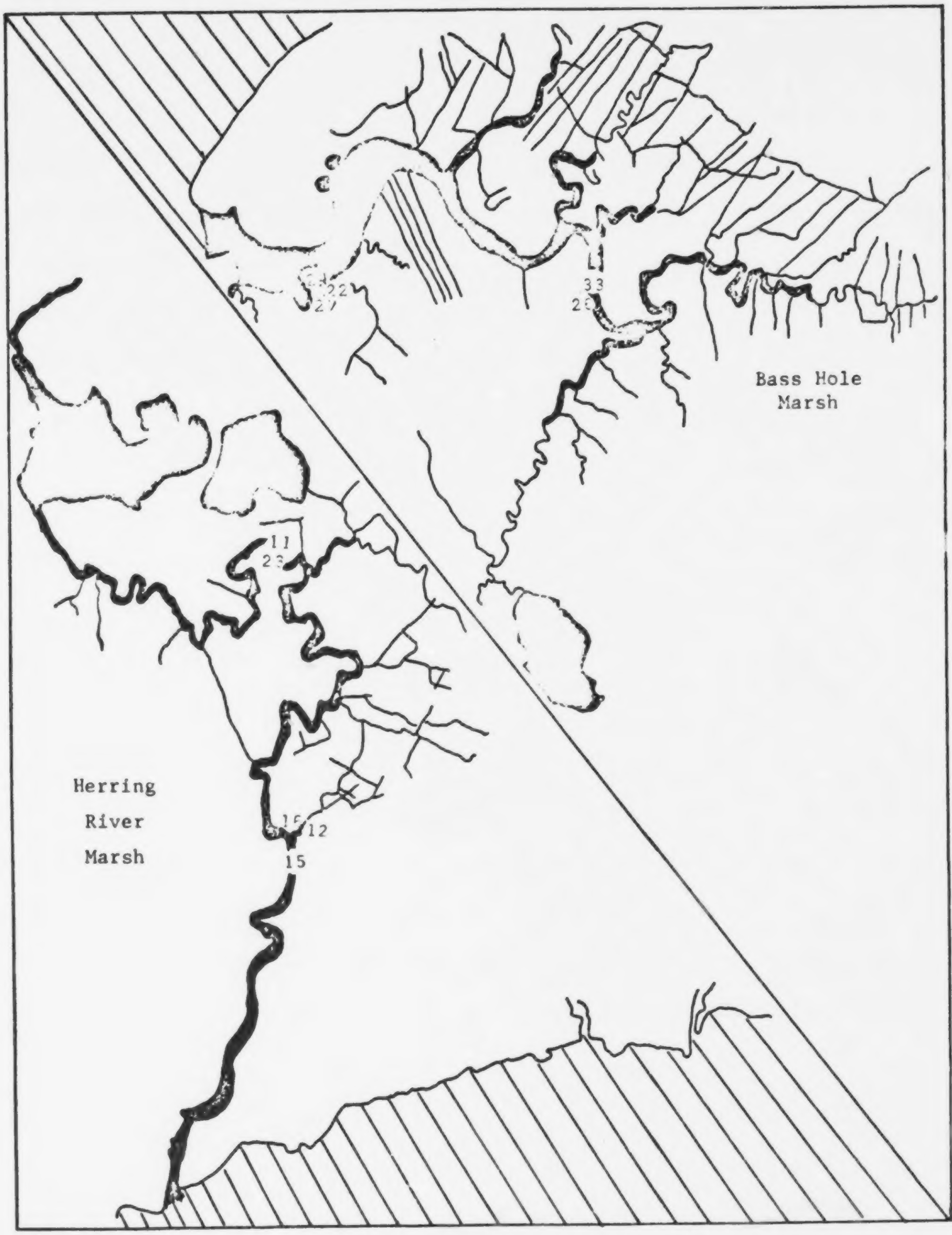
2. Biotic

General observations did not reveal major differences in speciation of either plants or animals between the two study areas, although differences in the distribution of fish are known. Sampling of water and taxonomic classification of the contained biota was conducted to determine the extent of large differences in the microflora and microfauna. Samples were taken of the main streams, feederstreams and mosquito control ditches during the ebb tide to obtain material derived from the marsh rather than from the sea and in a manner designed to eliminate any bottom sediment. Formaldehyde was used at proper concentrations to assure the successful preservation of both plant and animal specimens.[4,5]

Microscopic examinations revealed that the water samples contained a rather limited number of life forms. In order to statistically compare microbiota from the Bass Hole Marsh versus the Herring River Marsh, samples were concentrated prior to observation. Ten ml of each sample were centrifuged for one hour, the collected insoluble material was resuspended, and half of the volume was placed on a slide. Four quandrants on each slide were observed under a magnification of 264 X's. The location of sampling sites in our two study areas is indicated in Figure VI-1.

FIGURE VI - I

LOCATION OF SAMPLING SITES


22
27
33
26
Bass Hole Marsh
11
23
Herring River Marsh
16
12
15

Two samples from the lower Herring River Marsh (12 and 16) and two samples from the upper Bass Hole Marsh (33 and 34) exhibited only higher plant debris and detritus with no organized life forms (visible at 60 X's magnification). The plant debris found in all samples was presumed to originate from Spartina grasses. Animal life forms, crustacea and nematinea, were seen only in one Herring River sample (number 11) and in two samples from the Bass Hole Marsh (26 and 27). Other than these animals, the most commonly found life forms were filamentous algae, (none blue-green) colonial algae, diatoms (mostly Cymbella, a freshwater genus)[6] and a dinoflagellate.

Based upon these samples, the two marshes appear to be nearly identical in those microscopic organisms which reside at the base of the food chain. Therefore, descriptions of much of the environmental relationships in this report will apply to both areas, although specific exceptions, especially in regard to fish life will be made.

3. Biodynamics

The primary chemical energy production in the marsh occurs in the vascular plants which utilize radiant energy for photosynthetic food production. These plants decompose slowly and enter the water as organic detritis which, together with absorbed bateria, fungi, protozoa and algae, become the important food source for most of the marsh animals.[7]

The salt marsh and associated estuarine ecosystem is a highly productive environment. It is richer in nutrients and has a higher annual production rate than any other sea or land areas with the exception of cultivated areas.[8] It has been estimated that tidal marsh ecosystems produce approximately 3 tons/acre of dry plant material per year, as a result of the nutrient cycle trap effect of the estuaries.[9] The most important factor in this effect is the binding capacity of the fine sediments which allows them to contain large quantities of adsorbed nutrients, trace metals and other materials.[10] There is also a trapping effect caused by the vertical movement of water masses of different salinities and hence densities and the favorable oscillating tidal currents.[11] Nutrients are added to the sediments by the decay of marsh as well as marine organisms, and through the process of biodeposition in which filter feeding molluscs and crustaceans remove large amounts of suspended particles from the water and excrete fecal pellets or pseudofeces. These more concentrated organic foodstuffs may be eaten by deposit feeding organisms or become part of the nutrient store of the sediments. Once "trapped" and adsorbed by the sediments nutrients are easily released for reuse by the primary producers.

The organic detritus in the sediments is decomposed by intensive microbial activity which through the sulfur, nitrogen and phosphorus cycles release usable ammonia, phosphate and nitrate from complex organic compounds. The burrowing animals and filter feeders present in the marsh environment also release nutrients from the sediments by bringing them to the surface.

The tides are very important in the nutrient cycles of the marsh. Decomposition occurs where there is ample moisture and exposure to air. This is both the source of detritus and a means of releasing much of the nitrogen, phosphorus, and other plant nutrients which are then available for synthesis into forms which plants can use. Unused nitrates and phosphates, however, also move out with the tides and become a nutrient source for the bay plant life as well as settling to the sediment bottom.

Water movements, as well as salinity changes play an important role in determining what organisms live in any particular marsh as well as the distribution of those organisms.[12] For example, the distribution of mussel larvae may be determined by the magnitude of the tide at the time of settling.[7] Since they are filter-feeding animals, their rate of growth is determined by the length of time they are covered by water and by the amount of food brought to them by the tide.

Relatively few plant and animal species are able to adapt to the marsh environment. It is an area of extremes involving changes in salinity, temperature, and desiccation. Those that have been able to adapt remain relatively free of predators and competing species allowing them to occupy a broader niche and to be more abundant than otherwise would be possible.

Of the limited number of life forms which have successfully adapted to the salt marsh ecosystem, nearly half are terrestrial species, common throughout the grassy areas and on higher ground. These species have made only slight adaptation to the marsh ecosystem and are represented primarily by insects and arachnids. Many of these insects live and feed directly on the *Spartina*, eating either the tissues or the juices as well as using the plants for protection from the incoming tides. Others are mud dwelling and feed on detritus. The birds comprise the major remaining segment of the terrestrial species, along with a few racoons and rodents.

Of more importance to the energetics of the marsh are the estuarine and aquatic marsh species. With the estuarine species are zooplankton such as copepods and larval forms of invertebrate species such as shrimp, mussels, annelids, crabs, snails, and clams, as well as most stages in the life cycles of many species of fish. These animals primarily occupy the lower borders of the marsh because they are not able to withstand exposure. Several species of larger invertebrates live on the marsh surface and in the creeks. Many of these are burrowers, using the mud to avoid exposure at low tide and as a constant salinity and temperature source. Those that do not burrow usually maintain shells which can be completely closed to avoid drying. Amphipods, blue crabs and shrimp are found in the main stream; worms, oysters and mud snails are found in ditches; ribbed mussels, periwinkles, fiddler crabs and marsh crabs are representative of those animals found on the marsh surface. It is among these larger invertebrates that one finds the animals of most importance to the energetics of the marsh ecosystem. Filter feeding animals such as the mussels, clams, and polychaete worms remove large quantities of suspended particles from the water consolidating the nutrients for use by such deposit feeding marsh animals as the annelids, nematodes and periwinkles. It has been estimated that a marsh area contains approximately 3,673,000 mussels per acre each capable of pumping 1.2 gallons of water per hour,[7] thereby removing tremendous quantities of detritus and suspended nutrients. The deposit feeders return the nutrients to the sediments where they remain available for reutilization by the marsh ecosystem. Burrowing animals (particularly crabs) rework the surface of the marsh at low tide and further concentrate organic matter in their feces, thereby having a considerable influence on other populations.

The primary producers available in the low marsh at low tide are the mud algae, large algae and *Spartina alterniflora*. These together with organic detritus form the first step of the food chain. The low marsh consumers include amphipods or beach fleas, marsh crabs, fiddler crabs, green crabs, marsh insects (who venture down to the intertidal area at low tide) and periwinkles. Few secondary consumers (carnivores) are present in the low marsh at low tide.

The primary producers in the high marsh at low tide are the large algae and *Spartina patens*. These together with organic detritus are eaten by the primary consumers which include periwinkles, marsh snails, beach fleas and insects. Secondary consumers include spiders which feed on insects, birds such as rails, crows and sandpipers which feed on periwinkles, snails and beach fleas, and song birds which feed on insects.

When the tide comes in the food chains of the marsh change. Many animals decrease their activity at this time. Insects climb up or into Spartina stems, birds retreat to their nests or higher ground, crabs either climb plants (marsh crab), or burrow (fiddler crab) or become active (mud crab, green crab and blue crab). Plankton is added by the tide as an additional foodstuff to the first step in the food chain. Filter and deposit feeders (mussels, barnacles, annelids and sand shrimp) increase their consumption. Isopods, fish and invertebrate larvae are also swept into the marsh as a food source for worms, shrimp, clams and crabs. Finally a new population of secondary consumers, the larger fish, are introduced as top carnivores for whom most of the marsh invertebrates function as a food source.

4. Species in the Cape Cod Marshes

a. Plants

The plants growing in the two Cape Cod salt marshes of our study may be classified by their specific habitat; the lower border, the meadow, the panne, and the upper border. The lower border of the marsh begins below the point of mean low tide and includes the edge of the meadow which is highly saline. Eelgrass (*Zostera marina*) grows below the low tide point where it is continually covered with sea water. Above the mean low tide region salt water cordgrass (*Spartina alterniflora*) dominates the edge of the meadow with its mat of roots holding in place the underlying layer of peat and helping to prevent extensive erosion of the marsh by wave action.

Beyond the salt water cordgrass region, the marsh opens out into a relatively flat meadow which becomes flooded for a while at every high tide., The saline concentration of the meadow is lower than that of the lower border and consequently different plants inhabit this area. The meadow comprises the major portion of every marsh, and salt meadow cordgrass (*Spartina patens*) is the most common and most important plant here.

Frequently one encounters shallow depressions in the midst of the meadow which are called pannes and contain water that is highly saline. Arrow grass (*Triglochin maritima*), seaside plantain (*Plantago oliganthos*), glassworts (*Salicornia sp.*), sea lavender (*Limonium nashii*), saltmarsh aster (*Aster tenuifolius*) and purple gerardia (*Gerardia maritima*) are all halophytes which inhabit panne regions and which we have observed in our study areas.

The upper border of the marsh begins at the mean high tide. It accounts for only a small percentage of the total land area of a marsh but is of significance in this study because it is where chemicals, if used, are applied for mosquito control. The plants in this region cannot tolerate much salt, and get flooded only during exceptionally high tides and storms. The orach (*Atriplex patula*), marsh mallow (*Hibiscus palustris*), saltwort (*Salsola kali*), sea-blite (*Suaeda sp.*), seaside goldenrod (*Solidago sampervirens*) switchgrass (*Panicum virgatum*), spike grass (*Distichlis spicata*), and common reedgrass (*Phragmites communis*) all inhabit the upper border. Black grass (*Juncus gerardi*), a dark green rush, is very common in this region especially in the Herring River Marsh, and shrubs such as the marsh elder (*Iva frutescens*) and sea myrtle tree (*Baccharis halimifolia*) begin to invade the marsh at the border. Poison ivy (*Rhus radicans*) is frequently common at the edge of the northern border, especially if the region has been disturbed by cultivation as at Bass Hole.[13,14,15]

In a marsh there are also many plants of lower phyla that cannot be identified without a microscope. The purple sulfur bacteria for example are anaerobic organisms which inhabit the oxygen free layer of mud just below the surface. Numerous kinds of diatoms and algae are found in the debris at the bottom.[16] Filamentous species of blue green algae are especially common. The totality of these unicellular and colonical organisms is usually referred to as phytoplankton. Although they are most important in the food chain, it is our belief that a discussion of their taxonomic classification does not contribute to an understanding of their role and has been omitted.

b. Animals

Just as the salt water marsh contains a variety of plant life, classes of which find a distinct niche dependant upon the salinity and maximum depth of water, so too, can distinct niches be allocated for the animal population of the salt water marsh. One of these niches is inhabited by fresh-water species, which live on the landward edge of the marsh. These animals include the big green darner (*Anax junius*), a high-flying species of dragon fly which feeds on mosquitos and other flying insects as an adult in the marsh but which as a nymph lives in fresh water.[4] Such species will not be enumerated here since this introduces a whole range of organisms and food chains which are only of peripheral concern to the marsh ecosystem. It is taken for granted that the marsh ecosystem and the fresh-water system which borders it would have some relationship implicit in the concept of natural interdependence.

A group of species which also have little inter-relationship with the marsh life are those terrestrial species which do live in the marsh. Many of these are insects such as the green-head fly (*Tabanus*), cinch bugs (*Ischnodesmus*), or tumbling flower beatles (*Mordellid*). Other terrestrial insects living in the marsh are specific species of grasshpper, plant hopper, sand fly, and ants. Other invertebrates in this niche are worms such as *Chaetopsis aena* and spiders such as *Lycosa modesta*. Among the vertebrates are the sea-side sparrow (*Ammospiza maritima*) and the rice mouse (*Oryzomys palustris*). Although many terrestrial species live their entire lifetime in the marsh, because of their greater adaptability they usually evidence less interaction with the true marsh ecosystem than species whose lives are more directly related to the estuarine water system and tidal pattern.

TABLE VI-1

MAJOR ANIMALS OF THE CAPE COD INTERTIDAL BIOMASS*

Gem Shell (*Gemma gemma*)
Annelid (*Streblospio benedicti*)
Annelid (*Lumbrineries tenuis*)
Annelid (*Heteromastus filiformis*)
Metanemertean Worm(*Amphiporus sp.*)
Spire Shell (*Hydrobia minuta*)
Ostracod (*Ostracoda spp.*)
Blood Worm (*Glycera dibranchiata*)
Moon Shell (*Polynices duplicata*)
Common Synapta (*Leptosynapta inhaerens*)
Heteronemertean Worm (*Micrura leidyi*)
Plumed Worm (*Diopatra cuprea*)
Annelid (*Scolopus fragilis*)
Polychaete Worm (*Eteone heteropoda*)
Polycheate Worm (*Pygospio elegans*)
Bamboo Worm (*Cylmenella torquata*)
Mud Snail (*Nassarius obsoletus*)

* Animal species present at concentrations of greater than $1 g/m^2$ in Barnstable Harbor in 1959 [18].

TABLE VI-2

INVERTEBRATES COMMONLY FOUND IN CAPE COD MARSHES

MOLLUSCA

Duck Clam (*Macoma balthica*)
False Angel Wing (*Petricola pholadiformis*)
Oyster (*Crassostrea virginica*)
Razor Clam (*Ensis directus*)
Channeled Whelk (*Busycon cannaliculatum*)
Bay Scallop (*Aquipecten irradians*)
Oyster Drill (*Urosalpinx cinerea*)
Ribbed Mussel (*Modiolus demissus*)
Periwinkle (*Littorina littorea*)
Blue Mussel (*Mytilus edulis*)
Quahog (*Venus mercenaria*)
Long-Neck Clam (*Mya arenaria*)
Marsh Periwinkle (*Littorina irrorata*)
Land Snail (*Melampus bidentatus*)

ANNELIDA

Clamworm (*Nereis virens*)
Trumpet Worm (*Cistenides gouldii*)
Polychaete Worm (*Harmothoe extenuata*)
Polychaete Worm (*Nephthys ciliata*)
Blood Worm (*Glycera dibranchiata*)
Plumed Worm (*Diopatra cuprea*)

NEMERTEA

Heteronemertean Worm (*Cerebratulus lacteus*)

SIPUNCULOIDEA

Sipunculoid Worm (*Golfingia gouldii*)

ARTHROPODA

Acorn Barnacle (*Balanus improvisus*)
Spider Crab (*Libinia spp.*)
Horseshoe Crab (*Limulus polyphemus*)
Lady Crab (*Ovalipes ocellatus*)
Green Crab (*Carcinides maenas*)
Rock Crab (*Cancer irrovatus*)
Jonah Crab (*Cancer borealis*)
Fiddler Crab (*Uca pugnax*)
Mud Crab (*Neopanope texana*)
Blue Crab (*Callinectes sapidus*)
American Lobster (*Homarus americanus*)
Isopod (*Cyathura polita*)
Isopod (*Idotea baltica*)
Common Prawn (*Palaemonetes vulgaris*)
Common Sand Shrimp (*Crago septemspinosus*)
Eel Grass Shrimp (*Hippolyte zostericola*)
Opossum Shrimp (*Mysis stenolepis*)
Amphipod (*Amphithoe rubricata*)
Amphipod (*Amphithoe longimana*)
Marsh Crab (*Sesarma reticulatum*)
Plant Hopper (*Prokelisia marginata*)
Greenhead Fly (*Tabanus nigrovittatus*)
Sand Fly (*Culicoides canithorax*)
Carpenter Ant (*Camponotus pylartes*)
Salt Marsh Mosquito (*Aedes sollicitans*)
Monarch Butterfly (*Danaus plexippus*)
Luna Moth (*Tropaea luna*)

A more detailed investigation can reveal enormous diversity of species in the estuarine habitat.[20] Thus 49 different Foraminipherans were found in the lagoon and estuaries of Buzzards Bay on the south shore of Cape Cod.[22] Random sampling in Barnstable Harbor at the mouth of the Bass Hole Marsh of the intertidal fauna revealed 24 different annelids[18], and of the more than 1300 common invertebrate marine animals found in the shallow waters of the North Atlantic Coast, 35 common species of ribbon worms can be found.[20] Omitted from Table VI-2 are those phyla with only minimal representation in our study area such as the Coelentera which contributes the burrowing sea anemone (*Edwardsia*), the turbellarians of the Platyhelmia and the Echinoderms such as the keyhole sand dollar (*Mellita testudinata*).

Among the Arthropods especially, an enormous diversity of speciation is found; enumerable different species live in the salt marshes of Cape Cod. The same is true for ants, grasshoppers and spiders. The listing of a single mosquito species is, of cours, also a simplification since it has already been stated in this report that more than twenty species of mosquitoes of seven genuses have been found on Cape Cod.[23] However, *Aedes sollicitans* is able to tolerate the highest salinity within the marsh and, thus breeds more out into the marsh itself rather than in the less saline water of the salt marsh border.

To supplement our literature searches, a small beach seine was used by the Division of Marine Fisheries, Department of Natural Resources, Commonwealth of Massachusetts to sample the fish population at the mouth of the Bass Hole Marsh. Those fish trapped in the seine included the four spine stickleback, winter flounder fry (locally called blackbacks), mummichog, American eel and a small number of pipe fish. At this location, in addition, cunner and silverside were observed and, by observation, it was estimated that the mummichog represented the fish present in greatest density throughout

TABLE VI-3

FISH OF THE CAPE COD MARSHES

Blueback Herring *(Alosa aestivalis)*
Alewife *(Alosa pseudoharengus)*
Atlantic Menhaden *(Brevoortia tyrannus)*
Atlantic Herring *(Clupea h. harengus)*
American Eel *(Anguilla rostrata)*
Mummichog *(Fundulus heteroclitus)*
Striped Killifish *(Fundulus majalis)*
Atlantic Cod *(Gadus morhua)*
Atlantic Tomcod *(Microgadus tomcod)*
Fourspine Stickleback *(Apeltes quadracus)*
Threespine Stickleback *(Gasterosteus aculeatus)*
Northern Pipefish *(Syngnathus fuscus)*
Striped Bass *(Roccus saxatilis)*
White Perch *(Morone americana)*
Bluefish *(Pomatomus saltatrix)*
Mackerel Scad*(Decapterus macarellus)*
Northern Kingfish *(Menticirrhus saxatilis)*
Scup *(Stenotomus chrysops)*
Cunner *(Tautogolabrus adspersus)*
Tautog *(Tautoga onitus)*
Atlantic Mackerel *(Scomber scombrus)*
Northern Searobin *(Prionotus carolinus)*
Striped Searobin *(Prionotus evolans)*
Grubby *(Myoxocephalus aenus)*
Longhorn Sculpin *(Myoxocephalus octodecemspinosus)*
Lumpfish *(Cyclopterus lumpus)*
Tidewater Silverside *(Menidia beryllina)*
Atlantic Silverside *(Menidia menidia*
Windowpane *(Scophthalmus aquosus)*
Winter Flounder *(Pseudopleuronectes americanus)*
Yellowtail Flounder *(Limanda ferruginea)*
Northern Puffer *(Sphercides maculatus)*
Ocean Sunfish *(Mola mola)*
Goosefish *(Lophius americanus)*
Orange Filefish *(Alutera schoepfi)*
American Sand Lance *(Ammodytes americanus)*
Crevalle Jack *(Caranx hippos)*
Black Sea Bass *(Centropristes striatus)*
Sheepshead Minnow *(Cypronodon variegatus)*
Rainwater Killifish *(Lucinia parva)*
Planehead Filefish *(Monacanthus hispidus)*
Striped Mullet *(Mugil cephalus)*
Oyster Toadfish *(Opsanus tau)*
Big-Eye Scad *(Selar crumenophthalmus)*
Lookdown *(Selene vomer)*
Atlantic Needlefish *(Strongylura marina)*
Hogchoker *(Trinectes maculatus)*
White Hake *(Urophycis tenuis)*
Sea Raven*(Hemitripterus americanus)*
American Smelt *(Osmerus mordax)*
Rock Gunnel *(Pholis gunnellus)*

the Bass Hole Marsh. The mummichog, as well as the cunner, are more plentiful in the Bass Hole Marsh than the Herring River Marsh. In the Herring River Marsh, one would expect to find a relatively high number of alewife, striped killifish, scup, and Atlantic silverside. The distribution of fish in each marsh varies with time of year, stage of development and tide level. For instance, the large predator species move into the marsh only with the tide and then only when they are in the region. Striped bass, for instance, would be in the marsh from June to October as they come to Cape Cod along their migratory route. The same would apply for menhaden, but the marsh would also serve as a continual forage area for the young fish of this species. Mackerel, herring, sea herring, and dog fish would be found at the mouth of the marsh only.

The American eel, winter flounder, and alewife use the marsh at quite distinctive times in their developmental cycle. Thus the anadromous alewife use the Herring River as a major run. They spawn in the inland lakes, with the adults arriving there in late April. The juveniles descend into the salt marsh from July until the fall. Flounder spawn in the marsh and the young-of-the-year live there. By the second year of age these fish will only be found at the mouth of the marsh. The American eel by contrast spawns in salt water and arrives at one or two years of age with the female going up into the fresh-water ponds and the male staying in the lower marsh. They remain for several years before returning to the sea.

The blue fish or snapper is like the sea bass, except it is more prevalent on the south side of the Cape.[24] This is a transient species which also makes a summer run and will not enter into areas of decreased salinity in the marsh. Pipe fish are to be found the year round.

A complete listing of those fish species which have been observed in the salt marshes of Cape Cod is presented in Table VI-3. This Table does not indicate those fish for which only a single sighting was made such as the twospine stickleback at the Herring River or the haddock at the Bass Hole Marsh. The distribution of the fish between the Bass Hole Marsh and the Herring River is noted with attention drawn to the most common fish species.

The vertebrate class Chondrichthyes is represented by the skates (*Raja erinacea* and *Raja ocellata*) and smooth dogfish (*Mustelus canis*) at the mouths of both of the Marshes. Representation by the Amphibia and Reptilia is not significant in the Cape Cod Marshes with only an occasional fresh-water turtle, snake, or frog making an appearance in the marsh. A large number of bird species, however, are found in the Cape Cod marshes. A total of 384 species (including those now extinct or exterminated) have been reported for the entire Cape.[25] Sixty-eight bird species have been reported in Connecticut tidal marshes.[13]

Table VI-4 includes those birds most commonly found in the marshes.[26] No listing has been made of those species rarely observed such as the Osprey, King Rail and Black-Crowned Night Heron which are commonly associated with the estuarine habitat. A separate table has been prepared, however, Table VI-5, of those bird species of lesser occurence (between rare and common) but which are familar to the amateur ornithologist.

Mammals do not form an important part of the Bass Hole Marsh or Herring River Marsh ecosystem. Most come from the surrounding forest, such as the squirrels and carnivores. The little brown bat (*Myotis leucifugus*) does use the marsh as a feeding ground but does not live there. The moles, woodchuck, and field mouse enter that portion of the marsh which does not get flooded.

TABLE VI-4

BIRDS COMMONLY FOUND IN CAPE COD MARSHES

SUMMER RESIDENTS

Great Horned Owl *(Bubo virginianus)*
Red-Tailed Hawk *(Buteo jamaicensis)*
Sparrow Hawk *(Falco sparverius)*
Herring Gull *(Larus argentatus)*
Great Black-Backed Gull *(Larus marinus)*
Crow *(Corvus brachyrhynchos)*
Blue Jay *(Cyanocitta cristata)*
Robin *(Turdus migratorius)*
Starling *(Sturnus vulgaris)*
Bob-White Quail *(Colinus virginianus)*
Ring-Necked Pheasant *(Phasianus colchicus)*

WINTER RESIDENTS

Black Duck *(Anas rubripes)*
Goldeneye *(Bucephala clangula)*
Merganser *(Mergus merganser)*
Junco *(Junco hyemalis)*
Goldfinch *(Spinus tristis)*
Meadowlark *(Sturnella magna)*
Bufflehead *(Bucephala albeola)*

MIGRANTS

Greater Scaup *(Aythya marila)*
Marsh Hawk *(Circus cyaneus)*
Great Blue Heron *(Ardea herodias)*
Semipalmated Sandpiper *(Ereunetes pusillus)*
Laughing Gull *(Larus atricilla)*
Arctic Tern *(Sterna paradisaea)*
Coot *(Fulica americana)*
Wood Duck *(Aix sponsa)*
Green Teal *(Anas carolinensis)*
Blue Teal *(Anas discors)*
Flicker *(Colaptes auratus)*
Downy Woodpecker *(Dendrocopos pubescens)*
Song Sparrow *(Melospiza melodia)*
Grackle *(Quiscalus quiscula)*
Mourning Dove *(Zenaidura macroura)*
Barn Swallow *(Hirundo rustica)*
Semipalmated Plover *(Charadrius semipalmatus)*
Piping Plover *(Charadrius melodus)*
Black-Bellied Plover *(Squatarola squatarola)*
Whimbrel *(Numenius phaeopus)*
Greater Yellowlegs *(Totanus melanoleucus)*
Tree Swallow *(Iridoprocne bicolor)*
Savannah Sparrow *(Passerculus sandwichensis)*
Snow Bunting *(Plectrophenax nivalis)*

TABLE VI-5

OTHER BIRDS FOUND IN THE CAPE COD MARSHES

Screech Owl *(Otus asio)*
Saw-Whet Owl *(Aegolius acadicus)*
Duck Hawk*(Falco columbarius)*
Pigeon Hawk *(Botaurus lentiginosus)*
Bittern *(Botaurus lentiginosus)*
Clapper Rail *(Rallus longirostris)*
Woodcock *(Philohela minor)*
Common Snipe *(Capella gallinago)*
Mallard *(Anas platyrhynchos)*
White Winged Scoter *(Melanitta deglandi)*
Canada Goose *(Branta canadensis)*
Canvasback *(Aythya valisineria)*
Brant *(Branta bernicla)*
Hummingbird *(Archilochus colubris*
Marsh Wren *(Telmatodytes palustris)*
Lesser Yellowlegs *(Totanus flavipes)*
Seaside Sparrow *(Ammospiza maritima)*

The rest of the species within the marshes our study area can be subdivided by their relationship to the water. Thus there are estuarine species limited to the low-water level such as the hydrozoan (*Bouganvillia*), and razor clam (*Tagelus plebeius*); and estuarine species which live in the stream side marsh such as the blue crab (*Callinectes sapidus*). Estuarine species also occur well into the marsh including the annelid worm (*Neanthes succinea*). Aquatic species with planktonic larvae like the ribbed mussel (*Modiolus demissus*) and aquatic species living their lives entirely within our study areas as the isopod (*Cyathur carinata*) must also be classified as true marsh species.

Of considerable importance in the marsh in terms of numbers are microscopic animals such as protozoans, the trochophore larval forms of invertebrates, and the round worms found among the zooplankton. However, because of observation and classification difficulties in providing a discussion of those particular species found in the two study areas in the Cape Cod marshes and the complexity of their population dynamics[17], these microscopic animals have been largely omitted in the current discussion of the animal inhabitants of these marsh areas. They will only be discussed in relation to ecological interactions, important toxicological considerations, specialized roles in the food chain and rapid turnover.

Sanders[18] has indicated that the major elements of the biomass in the Bass Hole environs are the fifteen invertebrate species listed in Table VI-1, but there are hundreds of other species of invertebrates which inhabit the salt-water marshes of Cape Cod. Table VI-2 presents a sampling of these lower life forms[19,20,21]; note that other names may be used for some species. For example, the reader must make the association between the quahog, *Venus mercenaria*, *Mercenaria mercenaria*, round clam, hard-shell clam, little neck clam, cherrystone clam and all other names invented for the same organ

The only animals that can be called true residents are the muskrat (*Ondatra zibethica*), meadow vole (*Microtus pennsylvanicus*), white-footed mouse (*Peromyscus leucopus*) and the racoon (*Procyon lotor*).

5. Food Chains

Within the salt marsh itself, the feeding patterns are not entirely cyclic. Many of the predators are migratory and both birds and fish remove energy from the salt water marsh and contribute it to ecosystems in other locations. The loss of energy is more than made up for by the solar energy absorbed by the plants and the nutrients entrapped as a result of the tidal movements.

As in most ecosystems the plants form the basis of the food chains but the salt-water marsh is distinctive in the extent to which a large portion of the food chain is dependent upon the initial consumption of detritus. Only the insects, the blue crabs and the occasional mammals feed directly on the Spartina grass and this at a low level. It has been calculated that in a Georgia salt marsh less than 5% of the energy in the Spartina is consumbed by insects. The majority of the energy in this grass serves as an energy source in the form of detritus which, coupled with algae, is food for the bacteria, crabs, worms, and other filter feeders. The crabs and nematodes consume over 10% of the energy available to them[19] Phytoplankton release organic materials into the marsh and also serve directly as foodstuffs.[27]

The marsh crab consumes the cord grass directly and its fecal pellets contain nutrients which other animals can make use of. The fiddler crab feeds on detritus and on algae in the mud. Although not a filter feeder, this crab carries mud to his mouth where fine bristles screen out the nutrient material and leave the reduced mineral content behind. The fecal pellets of the fiddler crab also provide a more concentrated foodstuff which can then be consumed by worms and molluscs. However, 90% of the solar energy trapped by the Spartina and algae is removed from the land and enters the marsh water system.[19]

While it would be excessive to describe in detail those specific species which live on the microscopic aqueous flora and fauna of the marsh[28], it is important to realize the diversity of organisms which depend upon this mixture of diatoms and algae. In addition to the mussels already mentioned, the majority of molluscs are also filter feeders. Thus, spire shells and *Tellina agilis* feed on diatoms and *Aligena elevata* on algae. The dinemertineans, *Amphiporus* and *Cerebratulus lacteus* feed on similar microscopic food sources with the latter supplementing its diet with the aforementioned spire shell as well as *Odostomia*, annelids and the larvae of mussles. Other ribbon worms also consume polychaete annelids as evidenced by the setae found in their stomach contents.

Most of the annelids consume diatoms with additional consumption of nematodes by *Spio setosa*, other polychaete worms by blood worms, detritus by members of the *Scolopos* genus, *Eteone* and *Amphitrite ornata*, gem shell larvae by the clam worm, and crustaceans by the plumed worm. The spire shell is also consumed by the common synapta (*Synapta inhaereus*) which is an echinoderm. Diatoms, algae and detritus are consumed by such arthropods as *Carcinogammarus micronotus*, *Eupagarus longicarpus*, and the crabs previously mentioned. This diet is supplied by polycheate worms in *Edotea montosa* and with gem shells, nematodes and other crustacea in the common shrimp. The crustaceans as well as the other invertebrates are consumed mainly by fish. Fish also eat insects in the marsh. The sheepshead minnow, for instance, feeds on mosquito larvae. The herring consumes many invertebrates, but at early stages in its life may be consumed by jellyfish and predatory worms.[29]

Fish of the small size of the minnow, mummichog and silverside furnish food for the predatory species. While some predators, like the alewife which travels through the Herring River marsh, do forage in the marsh channels, many of them only enter the lower reaches of the marsh with the incoming tide. However, since the flow of energy is toward the sea, the marsh provides an especially rich source of organic foodstuffs, important to the growth of such carnivorous fish.

Amoung the birds commonly found in the Cape Cod marshes, the herring gull and great black-backed gull are primarily carnivorous in their feeding habits. The great blue heron feeds on fish as does the greater yellow legs and the greater scaup. The latter also consumes crabs. Black duck feed on intertidal animals as well as plants and seeds. The whimbrel feeds on fiddler crabs. Also feeding on crustacea and other mudflat animals are the semipalmated plover, piping plover, black-bellied plover, golden eye, and crow. A number of birds feed on seeds and insects in the marsh; the raptorial birds on rodents.

B. TOXICITY OF PESTICIDES

To determine the impact of the vectoricide pollution on the water environment we researched the literature for data relevant to the toxicity pesticides. Using data obtained with different animal species, it is then possible to postulate the effects which would be obtained on the distinct species found in our Cape Cod study areas. Acute effects are those which are experienced immediately (within 96 hours of exposure), while chronic effects are those seen upon extended exposure to a particular toxic compound. Carcinogenicity, mutagenicity, and teratogenicity are measures of quite specific toxic behavior which are not of great importance in relation to wildlife (but are of extreme concern insofar as man is concerned). Finally, sublethal concentrations of pesticides can produce biochemical and physiological effects which may be of importance.

1. Acute and Chronic Toxicity

Tables VI-6 to VI-10 present the pertinent data which indicate the lethal potential of the compounds Abate, DDT, Malathion, and Flit MLO. Additional data is also presented in Table VI-7 on the toxicity of decompositon products of DDT which have been found to be important in the environment because of their persistence. We have not included data which we do not believe to be relevant to our study area; e.g., the findings which have been obtained with the coturnix quail have been left out of these tables since this species does not inhabit our study area, and data relating to rainbow trout and other fresh water fish has been eliminated in those cases where a knowledge of the toxicity to saltwater species was available. Data relating to the toxicity of compounds to man has been left out since it must be obtained randomly and not from controlled experiments, and does not give a true indication of the toxicity of compounds. Information on the effects in man of various compounds mentioned (except Flit MLO can be obtained from our previous publication on "Organic Chemical Pollution of Freshwater."[56]

2. Carcinogenicity, Teratogenicity and Mutagenicity

Extensive work has been done on the carcinogenicity of DDT. Positive results have been found in the trout[57] and rat.[58] The production of tumors in mice was attained with lower concentrations of DDT than in any other species. Five generations of mice were fed DDT at 3 ppm of the diet for 6 months. One-third of these animals developed tumors.[59] DDT has also been found to produce C-mitosis (chromosome breaks) when administered as a saturated solution to plants.[60] Such mitotic chromosome breaks can be an indication of the mutagenicity of a compound. However, when fed to mice at

TABLE VI-6

ACUTE AND CHRONIC TOXICITY OF ABATE

REFERENCE	SPECIES	CONCENTRATION	EFFECT
30	Mosquito Larvae	0.4-11 ppb	LC 50
31	Juvenile Shrimp	0.020 ppm	EC 50
32	Amphipod	1.0-1.5 ppm	LC 50
31	Juvenile Killifish	1 ppm	No effect
33	Bullfrog	>2000 mg/kg	LD 50
30	Mallard duck	1200 ppm	LD 50
34	Mouse	4000 mg/kg	LD 50
35	Rabbit	10 mg/kg/day	Minor liver damage and necrosis

Effects are statistically calculated values for observations to be expected with an infinite population.

EC 50 = Concentration at which 50% of animals should show an effect
LC 50 = Concentration lethal to 50% of animals
TLm = Approximate equivalent of LC_{50}
LD 50 = Dose lethal to 50% of animals

TABLE VI-7

ACUTE TOXICITY OF DDT AND METABOLITES

REFERENCES	SPECIES	CONCENTRATION	EFFECT
30	Mosquito	12 ppb	LC 50
32	Amphipod	2-4 ppb	LC 50
31	Juvenile Shrimp	0.6 ppb	EC 50
36	Adult Shrimp	5.5 ppb	EC 50
32	Hermit Crab	7 ppb	LC 50
31	Juvenile Killifish	3 ppb	LC 50
37	Sheepshead Minnow	6 ppb	LC 50
38	Catfish	16 ppb	TLm
38	Carp	10 ppb	TLm
39	Fathead Minnow	32 ppb	TLm
38	Minnow	19 ppb	TLm
38	Guppy	43 ppb	TLm
38	Perch	9 ppb	TLm
33	Bullfrog	>2000 mg/kg	LD 50
33	Mallard Duck	>2240 mg/kg	LD 50
40	Mouse	150 mg/kg	LD 50
41	Mouse	580 mg/kg	LD 50
39	White Rat	113 mg/kg	LD 50
36	Shrimp	52 ppb DDE	LC 50
32	Amphipod	2-6 ppb DDD	LC 50
42	Rat	1060 mg/kg DDE	LD 50
32	Rat	3400 mg/kg DDD	LD 50

TABLE VI-8

CHRONIC TOXICITY OF DDT

REFERENCE	SPECIES	CONCENTRATION	EFFECT
46	Pigeon	40 mg/kg	Increased estradiol metabolism by liver homogenates
47	Mouse	0.4-0.7 mg/kg for 5 generations	Leucocytosis
48	Neonate Rat	1 mg	Significantly advanced puberty
42	Rat	500 ppm	Stimularion of hepatic microsomal enzyme
41	Rat	0.05 mg/kg daily for 6 months	Histological changes in liver, kidneys, myocardium, suprarenals and brain
49	Mallard Duck	10 ppm DDE	Decrease in reproduction

TABLE VI-9

ACUTE TOXICITY OF MALATHION

REFERENCES	SPECIES	CONCENTRATION	EFFECT
30	Mosquito	90 ppm	LC 50
32	Amphipod	2-4 ppb	LC 50
32	Hermit Crab	0.1 ppm	LC 50
38	Minnow	8.7 ppm	TL 50
37	Sheepshead Minnow	0.3 ppm	LC 50
50	Fathead Minnow	9 ppm	TLm
51	Guppy	0.84 ppm	TLm
38	Carp	6.6 ppm	TL 50
39	Catfish	9 ppm	TL 50
38	Perch	0.3 ppm	TL 50
33	Mallard Duck	1485 mg/kg	LD 50
51	White Rat	1375 mg/kg	LD 50

TABLE VI-10

ACUTE TOXICITY OF FLIT MLO

REFERENCES	SPECIES	CONCENTRATION	EFFECT
52	Mosquito Larvae	0.5 gal/acre	LD 50
53	Mosquito Larvae	1 gal/acre	LD 90
54	Grass Shrimp	8 gal/acre	No effect
54	Fiddler Crab	8 gal/acre	No effect
54	Mummichog	8 gal/acre	No effect
54	Bluegill	>40 gal/acre	MTL
54	Longnose Killifish	30 gal/acre	No effect
54	Domestic Duck	10,000 ppm	No effect
55	Rat	>10 g/kg	LD 50

105 mg/kg, DDT was not mutagenic.[61] DDT was also negative insofar as teratogenicity (the ability to produce congenital malformations when administered to the pregnant animal) in both the mouse[60] and the chick.[62] Tests for the toxic activity of DDT metabolites have also been made. DDD has been found to be negative for carcinogenicity when tested in the mouse.[63] It is also negative in the mouse for teratogenicity.[60]

The organo-phosphate insecticides have also been tested for their teratogenicity. In the ewe, Abate has been found to be negative for such effects.[64] However, malathion was injected into chick eggs at 75 ppm per day; congenital malformations were observed indicating a teratogenic potential.[65] No evidence for carcinogenetic potential has been found. Malathion fed to rats at 5000 ppm in their diet for two years gave a negative result insofar as the induction of tumors is concerned.[66]

3. Sublethal Effects

Sublethal effects are defined here as any adverse response, except death, due to insecticide application and/or accumulation in the biota. The majority of the literature concerning sublethal effects for the four insecticides under consideration deals with the DDT family of compounds, mainly because they are persistent in nature and can therefore be traced. The most notorious sublethal effect proposed for DDT is the current theory explaining the decrease in the populations of raptorial birds. These birds of prey are at the top of numerous food chains. Insecticide residues, especially chlorinated hydrocarbons, accumulate in these birds. The DDT residues may be stored in fatty tissues for long periods without conspicuous effects. In birds, fat reserves are then utilized during migration and reproduction.[67] Apparently, the presence of DDT stimulates the liver to form metabolizing enzymes which can act upon a variety of substances including the sex hormones which regulate the reproductive cycle.[68,69]

The decreased populations of these birds may be due to many factors:

1) delayed breeding or failure to lay eggs;
2) thinning of egg shells leading to much breakage;
3) eating of broken eggs by parents;
4) failure to produce more eggs after earlier clutches were lost;
5) high mortality of embryos and fledglings[70]

A direct correlation has been proposed between the thinning of raptorial bird egg shells and the presence of chlorinated hydrocarbon insecticides.[71] Calcium is deposited around an egg in the last 20 hours before laying. In birds, calcium metabolism is intimately related to reproductive metabolism [46] and is controlled by estrogen and parathyroid hormone. Ratcliffe[73] studied the incidence of broken eggs in the nests of sparrowhawks in England and suggested a cause and effect linkage between increased egg breakage, decreased egg weight, and exposure to persistent organic pesticides in the environment for the species examined. The reason that this type of sublethal toxicity is especially insidious is that concentrations of pesticide residues found *in vivo* are often quite low compared with a toxic dose.[69]

Species of birds which have not yet shown a population decrease may yet be in danger. Prairie falcon populations in North America have not decreased as have the peregrine falcons, but investigators predict that these birds will exhibit reduced reproduction due to eggshell thinning and related reasons. An inverse relationship has been established between eggshell thickness and levels of DDE in their eggs.[74] Wurster and Wingate[75] have pointed out that the susceptibility to chlorinated hydrocarbons varies considerably with different species of raptorial birds. These authors believe that aggressive behavior, increased nervousness, chipped eggshells, increased egg breakage, and egg eating by parent birds suggest symptoms of hormonal disturbance or a calcium deficiency or both.

DDT also exhibits other sublethal effects. It interferes with normal calcification of the arthropod nerve axon, causing hyperactivity of the nerve and producing symptoms similar to those resulting from calcium deficiency.[76] The DDT metabolites, DDD and DDE, have been found to affect the steroid metabolism of rats.[77] It has also been found that DDT disrupts osmoregulatory events in the intestine of sea water-adapted eels.[78] The eel avoids desiccation by consuming sea water and excreting ions through the gills. Adenosine triphosphatase enzymes are involved in the transport of sodium ions and apparently DDT impairs water absorption by inhibiting these enzymes.

The biochemical poisoning by sublethal amounts of DDT in other fish has also been investigated. Mayhew[79] described the symptoms of DDT poisoning in trout as marked irritability and sensitivity to vibrations, followed by a loss of equilibrium with muscular spasms and convulsion. The loss of coordination and other erratic behavior would seriously interfere with the ability of fish to get food. Goldfish exposed to a 1 ppm solution of DDT exhibited complete loss of balance.[80] EEG activity of exposed cerebellum tissue was then recorded. There was an increase in the amplitude and decrease in the frequency of the spontaneous electrical activity of the cerebellum. Finally, in experiments on the effect of DDT on the propellertail reflex, trout learned to exhibit this reflex with electric shock as an unconditioned stimulus and light as a conditioned stimulus. After a 24 hour exposure to 20 ppb DDT, 50% of the fish could not be conditioned at all, and the rest required significantly more trials than did the untreated control fish.[81]

It would appear that the principal site of action of DDT in the vertebrate organism is the central nervous system.[80] The organophosphate insecticides like malathion and Abate can also effect motor responses since they act at the site of the nerve muscle junction. By inhibition of the enzyme acetylcholinesterase in the nervous system these compounds depress or inhibit the transmission of nerve impulses. Abate produces a 70% inhibition of blood acetylcholinesterase when administered in the diet of rats at 200 ppm.[64] Malathion has been reported to produce a 65% inhibition of the enzyme within 24 hours of placing a goldfish in 0.1 mg/l of the organophosphate insecticide.[82] In the rat, inhibition of acetylcholinesterase activity in the brain has been observed.[83]

In non-vertebrates other effects are observed. Abate at 10 ppb in sea water causes a loss of equilibrium in juvenile shrimp.[84] A concentration of 170 ppb causes a 50% decrease in oyster shell growth. The minimum threshold level affecting oyster shell growth was found to be 100 ppb.[85] The protozoan ciliate, *Tetrahymena pyriformis*, is reduced in population by somewhat higher concentrations of DDT in its culture.[84] Finally, sublethal effects can also be observed in plants. Concentrations of between 1 and 100 ppb of DDT reduced the photosynthetic activity of cultures of diatoms, green algae and dinoflagellates.[86]

4. Extrapolation of Laboratory Results

The most important consideration in utilizing laboratory toxicity data for the estimation of the potential impact of these materials in the particular marsh environment or the environment at large, is that of making use of a limited number of toxicity determinations to an infinitely variable biological system. Thus, in the literature very little is available concerning the effect of insecticides or their toxicity to plants. One assumes that the low level of organic material in pesticides would not compromise the macroflora of an environment. However, in the estaurine environment present in the salt water marshes under study, the algal population is of great importance in both initially trapping energy by photosynthesis and in providing a major foodstuff for both filter and deposit feeders. Thus the phototoxic effects of a pesticide might be of great significance in evaluating its impact.

It was necessary in the preceding section to provide listings of the effects observed in many different species with each agent because the toxicological sciences have not arrived at a point where predictions can be made based upon examining a few model species. One extrapolates the toxic effect of a material from its effect on related organisms. Differential toxicity is common. For instance, it is well known that malathion is converted to the more toxic malaoxon more rapidly in insects than in mammals. This provides a safety factor in the use of malathion in normal agricultural insect extermination. In the salt marsh ecosystem, however, one must be especially concerned with a compound which has demonstrated a profound toxicity for invertebrate species.

Another difficulty in making extrapolations to an ecosystem is our general lack of knowledge of the multiple interactions involved. The salt marsh estuarine environment has been studied in significant detail insofar as multiple food chains and environmental niches which exist. These have already been discussed. However, one must always be concerned with the possibility that quite specific food chains or sensitive species which may be of importance can be missed in such an overview concerned mainly with the predominant species and the movement of the majority of chemical energy from sunlight to higher organisms and secondary consumers.

When toxicity testing is performed in the laboratory, pure compounds are utilized, and the absence of interfering substances assured. However, within the aquatic marsh ecosystem such is not the case. The water is a soup of diverse biochemicals and chemical interactions can be expected. Even if one were to catalogue the various materials present in the marsh it would not allow one to draw firm conclusions as to synergistic or interactive effects.

The importance of molecular interactions both in the environment and *in vivo* have only just begun to be investigated.[87]

The adequacy of the laboratory research must also be open to question. Many insecticidal materials have been measured for their toxic effect against fish at concentrations in which they are insoluble. Also, experiments have been performed in which it has later been found that most of the material has adsorbed to the containder in which the experiment was conducted. Analytical accuracy in relating concentrations of material to toxic effects observed may also be open to question. For instance, it is impossible in a study such as this to be sure that all data collected implicating DDT has in fact been obtained with this compound and not with polychlorinated biphenyls.

In nature, many compounds of low solubility will adsorb to the surface of detritus, mud and living plants.[88] As such, these adsorbed materials represent a new chemical species which was not investigated in the laboratory. Thus, how can one extrapolate to determine at what concentration an aquatic organism would be poisoned by a material present in solution as opposed to that same material present in an absorbed state? Would the toxicity be higher or lower in the latter case? Also, at what rate would the compound disassociate from the adsorbed state? In most cases such questions have not been answered but are of crucial concern where filter feeders and deposit feeders are concerned as in the estuarine environments which we are studying here.

C. IMPACT OF VECTORICIDES ON THE ESTUARINE ENVIRONMENT

Pesticides are applied to the marshes of Cape Cod by direct and localized hand spraying of bodies of stagnant water found to contain larvae. These bodies of water may be either pannes, upper channels (little influenced by the tidal motion of water), or low areas at the very border of the marsh which receive water during the monthly spring tide and in which such water remains unaffected by subsequent tidal movement. Concern with the movement of pesticides from the surface of grasses to primary consumers can be eliminated. Rather, our interest insofar as the initial distribution of the pesticide in relation to the biota of the marsh can be directed wholely towards the aquatic environment.

Solubility alters the immediate distribution of a particular pesticide. Compounds with water solubility such as Abate will disperse throughout the aquatic pool or channel. However, DDT can be expected to adsorb onto the surface of algae, detritus, and mud. Suspending agents have an effect on distribution.

The rate of disappearance of compound, whether by hydrolysis, reversible adsorption, vaporization, or other degradation is of great importance in determining toxicity. The half-life of the toxic structure in the environment is quite as important as its toxicity, since most toxic materials can be shown to have their effect in proportion to exposure, usually expressed as concentration times time (Cxt). A compound with a short half-life like malathion will exert its effect acutely, whereas a compound such as DDT with an exceptionally long half-life can be found to have subtle chronic effects. Relatively few controlled studies of pesticide duration have been performed in salt marshes.

Malathion, applied to soil at 3 parts per million, was found in a concentration in the soil of a tenth part per million after 8 days.[89] However, silt loam soil was involved in the study and would be expected to provide a less destructive environment to malathion than an aqueous environment with its assoicated organic muds and microorganisms. DDT, by contrast, applied to a highly organic forest soil at the rate of 1 lb. per acre has been estimated by Diamond *et al.* to persist for 30 years.[90] More directly relevant to our study area are the residues of DDT found in a Long Island marsh where the DDT in the water was estimated at 0.05 ppb.[32] In a Florida salt marsh treated with 0.2 lbs per acre of DDT, the water was found to contain from 0.3 to 0.4 ppm and the sediment as high as 3.5 ppm.[91]

Although some persistence is found among the organophosphate insecticides, it should be noted that these compounds are rapidly hydrolyzed in water and persist only when adsorbed to insolubles. It would be expected that Abate and malathion would have broken down to relatively non-toxic compounds prior to their reaching the mouth of the marsh either as dissolved organic materials or incorporated into the substance of food organisms. Actual physical transport of toxic compounds in the marsh is probably related more to the movement of persistent compounds through the food chain than the flow characteristics of the marsh water system.

Much of the data on the movement of specific pesticides in food chains will be covered in the next section in which the observed environmental effects of pesticides have been reported. However, to introduce this subject, an understanding of the ability of organisms to significantly concentrate pesticides is of utmost importance. A summary of this data is found in the government publication from the Office of Science and Technology, entitled, "Ecological Effect of Pesticides on Non-Target Species."[32] While this publication does not indicate concentrations of Flit MLO, Abate or malathion, it provides innumerable examples of the biological concentration of DDT. For instance, the eastern oyster concentrated DDT 70,000 times after being exposed to 0.1 ppb for 40 days; the croaker, a salt-water fish, concentrated 1 ppb DDT 20,000 times in a Long Island salt marsh, plankton concentrated the DDT over the water concentration 800 times; and fish in a Florida tidal marsh concentrated DDT up to 200 fold. In Lake Michigan alewife were found to have 10 times the DDT of amphipods, and the amphipods had 30 times the level found in the Lake mud.[32] Microscopic organisms also accumulate pesticides. After 7 days at 1 ppm DDT algae concentrated the compound 200-fold and, Daphnia concentrated DDT 100,000 fold. Those fish which ate the Daphnia concentrated the pesticide even further.[32] Investigators at Gulf Breeze, Florida observed that

DDT accumulation in the cells of *Paramecium multimicronucleatum* was 264 times greater and in *P. bursaria* was 964 times greater than in the medium on which they were cultured.[84] The occurrence of bio-concentration is what most often leads to the deleterious environmental effects observed when persistent pesticides such as DDT are used.

When an effective pesticide is used to eliminate bothersome organisms, the most obvious result is a decrease in the pest population. The success against mosquitoes of the four compounds under consideration (DDT, malathion, Abate, and Flit MLO)has been implied in our discussion of toxicity and is well documented.[92,93,94,95,96] However, there may also be other effects manifested immediately or at a later time. Insecticide usage may decrease the insect problem, but other organisms can be killed instead of or in addition to the target insects.

In order to curb the tick population on Bull's Island, South Carolina, DDT was sprayed manually and aerially on test plots.[97] The island is separated from the mainland by salt marsh and tidal creeks. The majority of the test plots were in forest regions, although part of one was on the salt marsh. Ond day after the marsh plot was sprayed with 2 lbs. of DDT/acre, 81% of the formerly abundant fiddler crab population was found dead and more were presumably dying buried in sediment. Two species of arboreal frogs had been abundant in the forest area, but they started falling from the trees within two hours after treatment. By the second and third days after spraying, a considerable number of these frogs were found dead or undergoing "DDT paralysis." The spraying was very effective in eliminating several species of mosquitoes and in decreasing the number of spiders, wood roaches, beetles, crickets, grasshoppers, ants, and harvestmen.

In an unpublished study, Abate was applied to test plots of a Cape Cod salt marsh with varying results.[95] When applied at a dose of 0.4 lb/acre, excellent control of *Culicoides melleus* mosquito larvae was obtained, although fiddler crabs were killed. When applied at a dose of 0.3 lb./acre, Abate was ineffective against the *Culicoides melleus* larvae, but fiddler crabs were killed again.

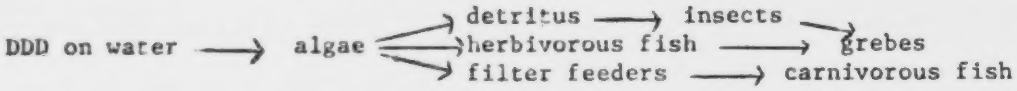
Crustaceans are quite susceptible to the three pesticides under consideration, and fiddler crabs, copepods and shrimp have been found to be adversely affected by them. When DDT was sprayed on salt marsh plots in New Jersey, a 75% kill of the copepod population was recorded on the first day, and by the second day the copepod population was seemingly eradicated.[96] On the 11th day after treatment, there was a 45% recovery; by the 12th day, the recovery was 80%; and on the 18th day the copepod population exceeded that of the control plot. As long as the insecticide is not continuously applied, the copepod population is able to reinstate itself. The investigators who sprayed DDT on a tidal salt marsh ditch in Florida concluded that the reproduction of all resident species of fish continued and restored pretreatment population levels in 4 months.[98] In this same experiment, however, a population of shrimp (*Palaemonetes sp.*) was drastically reduced, and the original population was not resotred in 4 months.

1. Biological Concentration of Pesticides

The environmental effects of pesticides are not always evident immediately after spraying. Deleterious effects are often not discernible for a long period after initial contact with a toxic material. It is commonly believed that biological magnification of pesticides and their residues occurs in food webs. A food web is composed of the interlocking food chains of an ecosystem, such as in a salt water marsh. In such cases, those organisms which do manage to survive exposure to pesticides and their residues are instrumental transmitting lethal and sublethal amounts of such materials to consumers, both herbivores and carnivores. A number of examples of biological concentration of pesticide residues in food webs pertinent to this discussion have been found.

The situation at Clear Lake, California provides a good example.[99,100] Clear Lake is a very popular tourist area which had a serious problem with gnats. The problem was recognized as early as 1916, and by September, 1949, it was finally decided that the lake should be sprayed with DDD. The formulation used resulted in an application of 1 part DDD in 70 million parts of water. The gnat larvae kill was reported to be 99%, but in 5 years, the gnat population had re-established itself sufficiently to warrant another spraying. Therefore, an application of 1 part DDD in 50 million parts of water was applied to Clear Lake in 1954, and again, the larval kill was 99%. This time, the gnat population re-established itself in 3 years. Another application of insecticide was made in 1958 using the same concentration of DDD. However, the percent kill of gnats was observed to be less than the percentages obtained from previous applications.

A few grebes were found dead soon after each application of DDD but 3 months after the 1957 application, approximately 75 grebes were reported dead on the lake's shores. Analysis of fatty tissue samples showed the concentration of DDD to be 1,600 ppm. Contaminated food was suspected to be the cause of death so local fish were collected and samples of their fatty tissue were analyzed. The amount of DDD found in the fat ranged from 40 ppm in carp to 2,5000 ppm in brown bullhead. Because there were no large-scale fish die-offs and since residue concentrations were higher in some species of fish(catfish and large-mouth bass) than they were in the grebes, it was concluded that grebes exhibit a weaker tolerance for DDD than certain species of fish. A grebe diet consists mostly of fish plus a few insects. Although these birds are subject to periodic die-offs, circumstantial evidence strongly suggests that the grebe losses were caused by chronic poisoning from DDD. It is believed that the DDD was accumulated in the food web shown below, although its presence in planktonic species of algae was not established.



It has been shown by other researchers that marine phytoplankton do contain DDT residues and that the uptake of these residues is rapidly and essentially irreversible.[101] Very low concentrations (a few parts per billion) of DDT in water reduced photosynthesis in laboratory cultures of four species of coastal and oceanic phytoplankton representing four major classes of algae and in a natural phytoplankton community.[86] Thus the presence of insecticide residues in the first link of the food chain is possible.

A salt marsh ditch on Santa Rosa Island, Florida, was sprayed with DDT for experimental purposes.[98] Eight of the 12 fish species present in the marsh ditch were placed in enclosed holding sites. The mortality of the confined fish was 37.7% at one site and 91.3% at another site close to the mouth of the ditch. Vegetation concentrated DDT residues to a maximum of 75 ppm 3 to 4 weeks after treatment. Fish and vegetation accumulated up to 1,500 times the maximum amount of DDT residues detectable in the water, while for snails and fiddler crabs the accumulation values were 144 and 99, respectively.

Evidence indicating the biological concentration of DDT residues was also obtained from an extensive salt marsh on Long Island.[67] The marsh was not treated with pesticides but had most likely accumulated residues from the river which empties into it. The concentration of residues in organisms increased with succeeding trophic levels; larger organisms and higher carnivores having greater concentrations. The concentrations of DDT residues in raptorial birds were 10 to 100 times those in the fish on which they feed.

Investigators at the University of Illinois designed a simulated ecosystem with a terrestrial-aquatic interface and a seven-element food chain which simulates the application of pesticides to crop plants and the eventual contamination of the aquatic environment.[102] They applied radiolabeled DDT and terminated the experiments after 33 days at which time samples were examined for DDT, DDE, DDD and polar compounds. The food chain pathways in the simulated ecosystem were:

$$\begin{tikzcd}
 & & \text{Algae} \arrow[r] & \text{Snails} \\
\text{Sorghum} \arrow[r] & \text{Salt marsh caterpillers} \arrow[ur] \arrow[r] & \text{Diatoms} \arrow[r] & \text{Plankton} \\
\text{Plankton} \arrow[r] & \text{Mosquitoes} \arrow[r] & \text{Mosquito Fish} &
\end{tikzcd}$$

It was demonstrated that mosquito fish concentrated and stored DDT in their tissues at a level which was approximately 11,500 fold over the level of radiolabeled DDT in the aqueous phase of the ecosystem.

Investigators at the Cranberry Experiment Station of Cape Cod, Massachusetts, devised a model cranberry bog, treated it with radiolabeled parathion (an organophosphate), simulated a frost protection flood 24 hours after treatment with the pesticide, and exposed fish and mussels to the run-off water.[103] The concentration of parathion in the flood water was 0.12 ppm and in the aquarium water it was diluted to 0.07 ppm. Only 20% of the fish (*Fundulus heteroclitus*) survived the 24 hour exposure in the aquarium. The dead fish concentrated the parathion to a level of 1.7 ppm, an amount 80 times greater than that in the water at the same period. After 48 hours the level rose to 2.11 ppm, but by 96 and 144 hours it dropped to 0.21 ppm. The mussels also accumulated a substantial amount of parathion, 0.99 ppm.

Measuring the levels of pesticide residues in dead organisms is useful for determining the rate of residue accumulation in the food web, but one may not assume that the organisms' deaths were a direct result of high residue levels, since such an assumption is invalidated by the fact that analyses of live fish have often indicated higher residue levels than those of dead fish from the same ecological conditions. The duration of exposure, the treatment dose, the extent of food contamination, the persistence of the insecticide and its breakdown products, and possible synergism, must all be considered.

2. Effects in Cape Cod Marshes

When it first became apparent that the concentrations of DDT and organophosphates in our study areas were very low, we noted in passing that these concentrations appeared too low to cause toxicity. In the case of our specific study area , it has been a year and a half since either an organochlorine or organophosphate insecticide has been applied for the purpose of controlling mosquitoes. Flit MLO has been used for spraying this year and only 21 gallons of 2% malathion solution were applied in all of 1970 (and that probably in the spring only). Thus, if we are to gain information about the possible effects which might have occured in the past as a result of the vectoricide program on Cape Cod, it is necessary to determine the concentration of vectoricides which would have been found in the marshes immediately following the appplication of malathion and Abate in the past, and of Flit MLO currently.

The data provided to us by the Cape Cod Mosquito Control Program[23] reveals that the greatest quantity of malathion applied to the Bass Hole Marsh was 83 gallons of the oil solution. In 1969, the peak use of Abate was experienced in our two study areas; 60 1/2 gallons of Abate solution were applied to the Bass Hole Marsh area and 38 1/2 gallons to the Herring River Marsh. The peak reported use of Flit MLO was in 1970 when 18 3/4 gallons were applied to the Bass Hole Marsh and 8 gallons to the Herring River Marsh.

The final concentration of malathion in the oil solution used was 0.17 lbs. per gallon and the concentration of Abate solution as applied was 0.003 lbs. per gallon. Thus, the maximum amount of organophosphate insecticide applied to either of the marshes in a single year was 14 lbs. of malathion in 1968 and 0.2 lbs. of Abate in 1969. However, these applications were made at several times and to several areas within the marshes.

The highest application rates of record for a particular vectoricide to a specific treatment site our study reveals the application of 10 gallons of oil solution equivalent to 1.7 pounts of pure malathion, 15 gallons of Abate (0.045 pounds) and 4 gallons of Flit MLO. By making use of the United States Geological Survey maps of the Dennis Quadrangle and Harwich Quadrangle and a compensating polar planimeter we determined the approximate acreage of these areas and calculated maximum application rates of 0.02 lb./acre malathion, 0.0006 lb/acre Abate and 0.04 gallon/acre Flit MLO.

While malathion has not been found to be toxic at the level applied the application of 0.02 lbs. per acre does approach the level of 0.1 lbs. per acre of the more toxic and active Dursban, which has been found to have killed fiddler crabs at this latter concentration.[95] The same studies did indicate however, that at the rate of 0.05 lbs. of Dursban per acre, no mortality to fiddler crabs or other organisms in intertidal sand plots was observed. Dursban has been found to be five times as toxic as malathion to invertebrates.[32]

It should be realized, however, that the hand applications of malathion at the maximal 0.02 lbs. per acre are to very limited areas of the marsh and even if some mortality were by some chance to occur in one particular area, immediate repopulation from adjacent areas would be expected. Also, the highest concentrations of pesticide were used early in the spring, prior to the appearance of the sensitive larval stage of most important fish species except the flounder.[104]

During the years when malathion was used in the greatest quantity in our study areas (1968 in the Bass Hole Marsh, and 1967 in the Herring River Marsh), the rate of application for the entire year was 0.013 lbs. per acre for the Bass Hole Marsh and 0.005 lbs. per acre for the Herring River Marsh. The maximum application of Abate over an entire season (1969) was 0.0002 lbs. per acre for the entire season in both the Herring River Marsh and Bass Hole Marsh areas. At 0.25 lbs. per acre, Abate is reported to cause no noticeable mortality of ostracods and copepods.

At these levels of application, it becomes impossible for us to be able to predict any significant toxic results within the marsh ecosystem. There indeed may be species sensitive to either of the organophosphates or to Flit MLO, but it must remain our conclusion that the local application of toxic pesticides to the two marshes which we have studied does not produce the risk of significant toxic effect to important species. Also, the current use of Flit MLO does not appear to have a lethal effect on any species in the marsh and, since this material demonstrates little toxicity after dilution, it is apparently of negligible concern to the generalized marsh ecocystem.

Numerous reports have appeared which indicate poisoning in estuarine environments,[105] but it becomes difficult to positively associate such effects with vectoricide programs in the face of the numerous other potential etiologic agents. Often, lethal effects in the marsh can as easily be assoicated with other sources of pollution, the effect of oxygen starvation, or an epizootic. However, some papers reveal concentrations of material (almost always DDT) in animals within marsh ecosystems which approach concentrations known to be toxic.[67] While this work is not to be denied, and while such data cannot be obtained from our study areas, a few comments concerning the possibility of significant toxic effects arising from a vectoricideprogram should be made.

DDT has no effect on salt marsh microorganisms when applied at levels as high as 1.75 lbs. per acre[106] but the concentration of such a persistent material through the food chain can result in a lethal dose for organisms at higher trophic levels in the food chain. However, in New England where DDT has been removed from use as a vectoricide, and few other organochlorine materials are used, the possibilities for build-up through the food chain have decreased and, thus, outright lethality as a result of vectoricide programs have become less critical. The immediate toxic effects of other pesticides would have been more easily observed in the course of their use.

Effects of poisoning other than by outright lethality must also be considered. Those animals which lose coordination as a result of the inhibition of acetylcholinesterase or, in the days of DDT, those animals whose eggs become less likely to survive, are indeed being poisoned by vectoricides while not being killed. The problem with documenting this kind of poisoning is that the results ofttimes lag significantly beyond the time of treatment. Here too, though, the demise of persistent materials has greatly overcome the problems associated with poisoning. Those organophosphate materials which produce a sublethal effect in organisms now are either metabolized in the organism and allow it to recover, or compromise the organism thus removing it from the population. The removal of organisms can have the effect of resulting in a food deficit for animals of higher trophic levels.

Starvation does produce a delayed effect although a close observation or population count of what are normally considered to be less important organisms could predict the eventual starvation of higher ones. It is possible that in some of the vectoricide programs currently in operation, decrease in the invertebrate population is, in turn, leading to malnutrition in higher life forms. While this may seem an unusual result, such malnutrition has already been observed in fresh water systems where the aquatic insects are most vulnerable to the use of pesticides.[107] In local fresh water marshes, for instance, a state of protein deficiency has been observed in young wood ducks, presumably as a result of a lack of the aquatic insect foodstuffs upon which they feed following hatching.

One area which is increasing as a problem is that involving synergistic effects.[109] The ability of several materials to produce a toxic situation greater than the sum of each individual materials' cannot be effectively evaluated. In many estuarine environments a variety of pollutants enter the environment and may have the opportunity to comprise already weakened organisms. It is possible in such situations to trace the multiple effects which have led to lethality, With agents other than traditional pesticides, (such as the Flit MLO, which is currently being used in the Cape Cod marshes) other questions will perhaps be raised in the future. At the present time, however, little in the way of detrimental effects on the biota of the salt marsh can be attributed to the use of Flit MLO. In fresh water, water boatmen bugs and certain beetle larvae and adults have been killed because they cannot get to the air above the larvicide oil.[110] In the salt water marshes, this would not appear to be a problem as analogous species have not been identified. Also, larger organisms such as the tadpole which does have to reach air, are not in any way interfered with by the mosquito larvicide oil.[110] This is not to say that problems in the future may not develop insofar as toxicity but no evidence based upon our study of either the literature or the Cape Cod salt water marshes indicates any such problem.

D. Impact of Vectoricides on Man

In discussing, finally, the impact of the vectoricide program in our Cape Cod study areas on man it is important to realize that the most dramatic effect of this program has been a beneficial one. There is no doubt that the vectoricide program has, in fact, yielded a high measure of control of the mosquito population of The Cape. A major benefit of mosquito control in the Cape Cod area, in addition to preventing the spread of disease, relates to improving the enormous recreational value of the area. At least part of people's desire to utilize the Cape Cod region is founded on the peace and uniqueness of the habitat as contrasted to the urban environment. It may be argued that in the absence of mosquitoes this is a false environment, but it truly cannot be argued that effective mosquito control permits a much larger number of people to observe and enjoy this environment more comfortably.

When dealing with the adverse effect of mosquito contol programs on man, however, esthetic considerations become difficult to resolve with the general question of human safety. Innumerable articles have appeared on this subject in both the lay and scientific press all introducing measure of philosophy in establishing the relative value of esthetic, toxicological and quality-of-life arguments. The economists have delved into elaborate systems for establishing the cost-effectiveness of both the use and control of pesticides and the commercial value of the preservation of distinct environments such as the salt water marsh. Writers have balanced the concept of elitism (in that it is the few who actually benefit from the utilization of wilderness areas) versus progress.[111] Scientists have written logical arguments for sanity in the evaluation of environmental problems.[112] While it is impossible to resolve the multi-faceted aspects of these philosophical discussions in general, certain points concerning esthetics can be raised in regard to the salt water marsh environment as found on Cape Cod.

The major fact arising from the previous section of this report is that little or no toxic effects arise from the use of vectoricides for mosquito control as currently practiced in our two study areas on Cape Cod. Mosquitoes are killed, and when toxic chemicals were used previously, it is probable that death resulted to a small percentage of certain sensitive invertebrate species. However, because of the short half-life of these particular insecticides, malathion and Abate, the effect of the poisoning of such invertebrates was not passed down the food chain (we are not concerning ourselves here with any hazards which may exist for the applicators).[113]

It is a strange quirk of man that esthetics apparently relates to birds a great deal more than it does to arthropods. Man can make much greater arguments for preventing diminished numbers of bald eagles and ospreys than he can for the decimation of lowly slime-entombed invertebrates. If our calculations are correct and the birds of the Cape Cod marshes are not affected by the mosquito control program and few mammals and other land invertebrates will be affected, we can resolve the esthetic argument down to a question of the extent to which periodic, localized decreases in invertebrates will affect the "esthetics of the salt marshes" as related to man.

Before drawing a final conclusion, it is important to remember that the basis for the mosquito control program currently being utilized in the Cape Cod salt marshes is ditch digging.[23] An aerial map of our study are reveals extensive major drainage ditches present in these marshes (36.7 surface miles in Chase Garden Creek section of the Bass Hole Marsh) which are kept in continual repair, both by brush cutting in the summer and reditching in the winter.[23] This method of controlling mosquitoes definitely does affect the marsh ecosystem.[114] The specific changes in fauna which accompany this increased drainage and their importance insofar as food chains have not been determined. However, in the Bass Hole Marsh the southern regions abutting Whites Brook contain extensive pannes with their associated distinctive vegetation. In terms of man, then, the negative effect of ditching would appear to be solely one of esthetic value insofar as the ditches leave a marsh "unnatural." However, ditching has been carried on throughout the northeast coast marshes for such an extended period of time that probably few people can now relate to an unditched marsh.

If esthetics are discounted and toxicological hazards eliminated it is then economic considerations which are left. It was repeatedly indicated at the start of this section that the salt marsh is a major factor in the feeding of large fishes and shellfish which are of economic value. Proceeding in phylogenetic order, one can evaluate stepwise the economic impact of the mosquito control program in these marshes. In some New England marshes, salt hay and seaweed are a cash crop[115], but have little economic value on the Cape. However, in addition, the marshes under study are not heavily involved in the shellfish harvest which is significant on Cape Cod. No mussels are harvested in either of our two study areas as in the nearby North River, and the Herring River Marsh especially does not encourage the organized harvest of soft shell clams. The Bass Hole Marsh does feed into Barnstable Harbor in which a reasonable amount of clam-digging is performed. However, the number of soft shell clams harvested at the mouth of the Bass Hole Marsh must be considered to be below the 1300 bushels harvested from the North River in 1965 [116] and thus below a value of $15,000 per year. This figure does not include the number of shellfish removed from Barnstable Harbor by family diggers, licensed to use the clam flats.

There is an organized culture clam venture located near the mouth of the Bass Hole Marsh and water is drawn from the marsh to nurture the spawn and young clams in these commercial pools. There have been occasional "clam kills" at these pools, but there has not been any evidence linking them to the organized vectoricide program conducted in the Bass Hole Marsh. These clam kills may be the result of other insect control programs such as tree insect control, or they may also be the result of natural failure of seed clams (biochemical analysis of the dead clams could not be performed). The value of this organized commercial activity in jobs and dollar value has not been determined since it is a private and closely held organization.

The value of oysters and quahogs harvested as compared to the soft shell clam industry is negligible. Although lobster are occasionally found at the mouth of the Bass Hole Marsh, the area does not support an organized lobster fishery. Similarly, the value of fish caught directly in the marshes or in the mouths of thse marshes is negligible. There is little direct economic benefit as the result of sport fishery fees in these particular areas. However, the marsh does contribute to the nutrients consumed by the larger fishes which make up the North Atlantic commercial and game fishery. The extent to which the vectoricide program could decrease fish yields in the North Atlantic however, is probably small.

As has been indicated before, the menhaden consumes vegetation and, as such, can be considered a primary consumer of insecticides. Although the menhaden catch goes almost entirely into fish protein materials and into animal feeds and petfoods, it is important as the largest fish catch in the United States. Because no concentration step of lipophilic materials (such as DDT) occurs prior to consumption by the menhaden, one would expect that this fish would not greatly experience the effect of the vectoricide programs. By observation, there would also appear to be sufficient mummichogs, the other primary consuming commercial marsh fish, to serve their function as bait in the most heavily treated portions of the marsh.

With the carnivorous fish such as the striped bass and mackerel, a different situation exists. These fish consume smaller fish or invertebrates that have in turn consumed other animals or plants. As indicated in our section on the concentration of insecticides in food chains, these animals can be exposed to high levels of persistent pesticides and produce even higher levels within their body tissues. Besides making such exposed fish less desirable in commerce, this bioconcentration has the effect of producing toxic symptoms in such fish and, in fact, toxic levels of DDT have in the past been found in many fish species.[67] Even if such outright lethal toxic levels are not reached, levels which can be detrimental to behavior may arise and, as such lead to decreased survival opportunity.

In terms of our study areas on Cape Cod, however, it is reported that no DDT has been used in either the Bass Hole Marsh or Herring River Marsh in the last 10 years. Thus, little contribution to the DDT content of fish or their food can have resulted from the vectoricide program. Other sources of DDT, especially vaporization and atmospheric transport appear to be more significant in their contribution to the marine environment.[117] The malation and Abate which have more recently been used are not persistent in water or organisms. The insulating value of the food chain between the primary consumers and the carnivorous larger fish, which exist only in the mouth of the marsh, probably protect these species from the effect of either malathion or Abate.

One might make an argument for an overall decrease in the ability of the salt water marsh to trap nutrients into higher life forms if certain of the invertebrate classes are periodically decreased by the application of pesticides. While a severe depletion of food organisms at any point in the life cycle would, in fact, decrease the small fish on which the carnivorous and commercially important fish are dependent, such would appear not to be the case in Cape Cod marshes. The exceptionally low level of vectoricide material used, its restriction to the borders of the salt water marsh and the proven ability of the marsh life to rebound rapidly from this exposure to organophosphate materials, would indicate a lack of such involvement. Further, even if some small decrement in trapped nutrients in invertebrate animals were noted in the marsh, it is likely that this decrease in food supply by itself would have little effect on the commercial fishing in the face of the multiple other factors tending to decrease the fish population. Those factors include over-fishing, generalized water pollution, and commercial development of seaside areas, thus decreasing nutrient supply in other ways. Whereas the direct toxic effect of a persistent vectoricide on a species would have environmental impact, the effect of a decrease in the food supply at the current time would probably only represent a weak link in a chain with considerably weaker links.

The effect of Flit MLO is somewhat difficult to assess. The inability to determine true toxicity is both a hindrance but also an indication of the unique nature of this material. It is highly refined mineral oil, and its effect is to temporarily form a barrier to prevent organisms from obtaining atmospheric oxygen. Such a barrier appears to be quite effective in causing the death of mosquito larvae, but the number of other aquatic species that use atmospheric oxygen rather than dissolved oxygen is quite limited. For instance, large schools of mummichog in the upper channels of the Bass Hole Marsh have been observed living without distress under layers of oil.

If such oil were to remain for a considerable amount of time in the upper reaches of the marsh, oxygen depletion would occur. However, the oil film has a limited lifetime and we cannot hypothesize any significant impact upon the marsh fauna caused by oxygen deprivation. The fact that the Flit MLO is sprayed by hand specifically into stagnant aquatic areas would also tend to negate the importance of its lipophilic character in interfering with land-based life. The Flit MLO thus may alter the appearance of the upper marsh channels for a couple of days following use, but would appear to be innocuous to man as currently used in our Cape Cod study areas.

While it is quite obvious that the extensive use of persistent pesticides can have a disruptive effect on the ecology of productive salt marsh areas, as has been observed experimentally and has been hypothesized on the basis of decreased production accompanying the use of DDT, it would appear that except for decreasing the population of mosquitoes and, thus, perhaps compromising those species directly dependent upon the mosquito as a foodstuff, the impact of vectoricide pollution on the water environment of our Cape Cod study areas is negligible. Also, in summary, it would appear that the impact of vectoricides on man, based on the mosquito control program as practiced on Cape Cod, can only be concluded to be, on balance, advantageous. The mosquito population has been reduced, thus, all but eliminating a disease threat and improving the recreational aspects of the land area. At the same time, there has not been an evidenced decrement to either the esthetic or economic value of the estuarine environment.

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VII. DEGRADATION OF PESTICIDES AND METABOLITES IN THE WATER ENVIRONMENT

In varying degrees, pesticides may be contaminating and accumulating in man's food supplies as well as the soil, water, and air of his environment. In this study, we have surveyed the literature pertaining to the degradation and metabolism of two chlorinated hydrocarbon pesticides--DDT and dieldrin--and two organophosphate insecticides--malathion and Abate--under a variety of environmental conditions. The choice of pesticides studied in this section was based on those chemicals which have at some time been used for vector control in the area of our study.

A. INTRODUCTION

Studies of pesticide metabolism are necessary for several reasons. From a practical viewpoint, information on the chemical behavior and reactions of insecticides in biological systems is essential for the rational assessment of hazards arising from the use of these compounds for vector control. Clearly, the identification and establishment of the toxicological properties of the metabolic products produced in plants, animals or by environmental factors are mandatory before residual hazards may be assessed. (Such toxicity effects will be discussed in another section of this report.) In addition to assessing the toxicological effects, data on the metabolic breakdown of pesticides, particularly in animals and microorganisms are basic to our understanding of the mode of action of such chemicals. Such information is of paramount importance for the elucidation of the intoxication and detoxification processes that occur in animals, plants, and microorganisms.

As shown in Figure VII-1, when a pesticide is applied to plants, animals, soils, water or air, there are many factors that may effect chemical changes. The rates of such alterations will depend on the nature of the

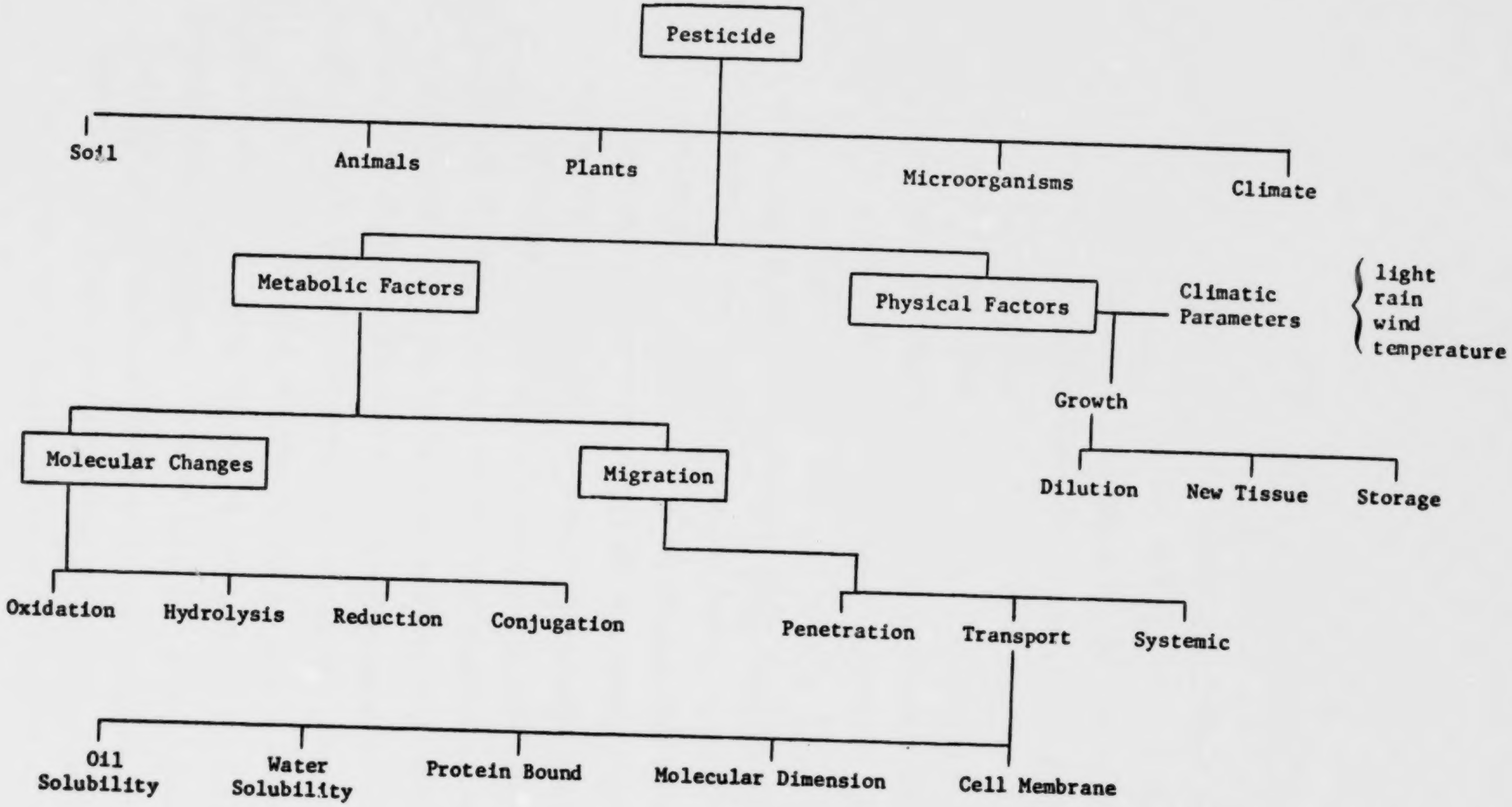

Pesticide
Soil
Animals
Plants
Microorganisms
Climate
Metabolic Factors
Physical Factors
Climatic Parameters
light
rain
wind
temperature
Growth
Dilution
New Tissue
Storage
Molecular Changes
Migration
Oxidation
Hydrolysis
Reduction
Conjugation
Penetration
Transport
Systemic
Oil Solubility
Water Solubility
Protein Bound
Molecular Dimension
Cell Membrane

FIGURE VII-1

FACTORS AFFECTING THE FATE OF A FESTICIDE pesticide and the particular environmental conditions to which it is subjected. Various metabolic and physical factors will influence the fate or rate of degradation of the parent pesticide. The metabolic factors as illustrated in Figure VII-1 will affect the fate of the pesticide and will involve either molecular alteration or migration phenomena. Molecular changes may be precipitated by chemical or enzymatic reactions such as oxidation, hydrolysis, etc. Migration in plants or animals may be considered to occur either through simple penetration or via more involved systematic transport mechanisms. Physical factors affecting the fate and persistence of pesticides are also shown in Figure VII-1.

In the soil, several factors have been reported to affect the behavior of pesticides. These factors include adsorption and desorption, volatilization from soil surfaces, movement in soils, uptake by plants and microorganisms, photochemical decomposition, chemical decomposition, (catalytic and hydrolytic) and microbial decomposition. All these factors contribute singly or in sequence in the processes of residue accumulation and/or pesticide degradation in the soil. These factors, particularly the last two, can equally influence the fate of the pesticide in water systems.

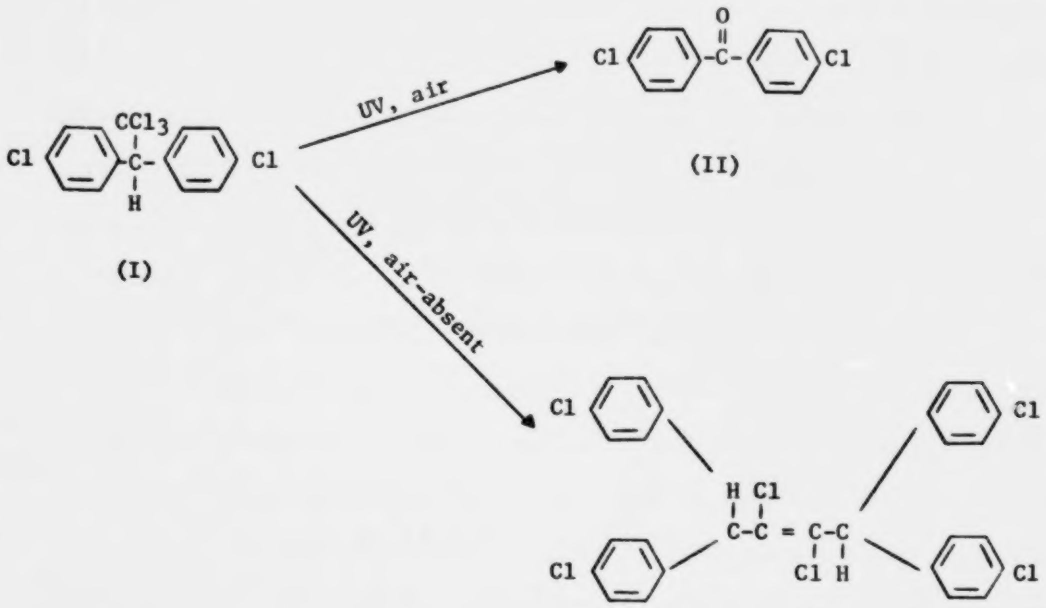
Photochemical decomposition on surfaces can be effected by the influence of sunlight[1] although it has only a practical energy range of 290 to 450 mμ. The mode of chemical decomposition can also be catalytic, (due to presence of nitrogenous constituents, carbonates, sulfates, as well as iron, manganese, cobalt, and aluminum salts) or hydrolytic (favored by the high or low pH of soils, i.e., pH 3 - pH 10). Microbial decomposition or biodegradation is brought about by the action of microorganisms like bacteria, streptomyces, fungi, and algae.[2,3,4] The process generally involves the following biochemical reactions--dealkylation, dehalogenation, hydrolysis, oxidation, reduction, hydroxylation, ring cleavage and conjugation.

The three types of decomposition discussed (metabolic, physical and photochemical) are believed to be the major pathways for conversion of pesticides into some other forms that can continue to persist or be further adsorbed and metabolized in the natural environment. These factors were taken into consideration in searching for and in sorting out currently available data. Likewise, whenever applicable, the extent of residue accumulation in soils and in natural waters was reviewed.

B. DECOMPOSITION MECHANISMS

1. Decomposition and Degradation of DDT

Photochemical degradation of DDT (I) by sunlight and heat or UV irradiation has been reported.[5,6,7] Both Broker[5] and Fleck[6] claim that in the presence of air, 4,4'-dichlorobenzophenone (DBP) (II) is formed, but when air is absent 2,3-dichloro - 1,1,4,4-tetrakis-(p-chlorophenyl) 2-butene (III) is formed.



(I)

(II)

(III)

The dechlorination of DDT in isopropanol by exposure to cobalt 60 γ-rays was studied by Sherman.[8] He found that at low and high dose rates dichlorodiphenylethane (DDD) is produced.

In the presence of small amounts of iron and aluminum salts, Fleck and Haller[9,10] report that DDT is converted to dichlorodiphenylethylene (DDE) (V). The dehydrohalogenation of DDT to DDE on homoionic clays was also reported by Lopez-Gonzales, et al.[11,12] DDE and DDD were also found in heavy clay soil in water sheds treated with DDT.[13] The active clay surface probably catalyzed the chemical decomposition. DDT is also converted to DDE by ammonia and other simple amines.[14] The conversion of DDT to DDE was greater in moist than in dry soils and was also increased by high alkalinity.[15]

The biodegradation of DDT by soil and water microorganisms under aerobic or anaerobic conditions can produce DDE (V)[16-19] or DDD (IV)[20-30] respectively. The metabolic route is a function of the specific microorganism and the presence or absence of air.[31] While several microorganisms are capable of metabolizing DDT, a number of others cannot degrade DDT.[32]

Several authors also reported on other probable microbial metabolites of DDT. Anderson[33] found five unidentified metabolites that were not identical with DDD, DDE, bis-(p-chlorophenyl)acetic acid DDA (VI), DBP (II), dicofol (VII), and 1,1-bis(p-chlorophenyl)ethane (VIII). The extensive studies of Focht and Alexander[34,35] showed that a *Hydrogenomonas* cleaved one of the rings of p,p'-dichlorodiphenylmethane (IX), a known DDT metabolite[35], and also that of diphenyl methane. The metabolites obtained were p-chlorophenyl acetate and phenylacetic acid respectively.

Wedemeyer[37] reported that *Aerobacter aerogenes* metabolized DDT by two different routes. By sequential analysis, he showed that one route takes the metabolic pathway DDT → DDD → DDMU (X) → DDMS (XI) → DDNU (XII) →

DDA (VI) → DBP (II). The further metabolism of DDA[36] follows the sequence DDA → DPM (IX) → DBH (VIII) → DBP (II). The second route involves direct conversion of DDT to DDE (VI), Patil, et. al.[28] claimed that of the twenty microbial cultures they studied, 10 isolates degraded DDT to a dicofol-like compound and 14 isolated degraded DDT to DDA.

Dimond[17] conducted his study in the associated soils of Maine forests from the first year of DDT application and for nine years thereafter. He found that the "total residue" included p,p'-DDT (main bulk of the residue), o,p'-DDT (14 to 20% of the total residue through the 9 years),* and DDE. The residue analysis reveals very little breakdown of DDT through the ten year interval, and the residues were confined to the upper organic soil horizons. Similar results were obtained by Lichtenstein[38] with DDT treated agricultural loam soils. The amount of p,p'-DDT plus o,p'DDT recovered 15 years after soil treatment was 10.6% of the combined dosage of 10 lb. per acre. Soils that had been treated with DDT at higher dosages showed relatively higher residue levels. DDE was the major metabolite found, but dicofol (VII) was also detected. Although the insecticides had been applied and washed into the soil to a depth of 5 inches, the 6-9 inch soil layer, 10 years later contained about 30% of the total DDT residues.

The studies of Swoboda, et. al.,[13] on heavy clay soils on three Blackland Prairie water sheds in Texas showed that less than 16% of the DDT (total of p,p-DDT, DDE and DDD) applied over a 10-year period was recovered in the top 5 feet of the soil. Between 60 and 75% of the recovered DDT was found in the top 12 inches of soil.

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*Note: Technical DDT consists of approximately 84% of p,p'-DDT and 15% o,p'-DDT.

Deubert and Zuckerman[39] reported on DDT residues in two cranberry bog soils in Massachusetts. They found that residue accumulation appears to be a function of the irrigation system used. Other workers have studied the problem of DDT accumulation in soils and the general consensus is that DDT tends to persist in contaminated areas to a large or small extent depending on the particular environment.[40-51]

Studies have also been reported on the fate of DDT in the lentic environment,[52] in rivers,[53] lakes,[54-56] sea water,[57] in marine organisms along costal California,[58] and forest streams.[59] The presence of residual DDT and the metabolites DDE, DDD and DDMS was reported.

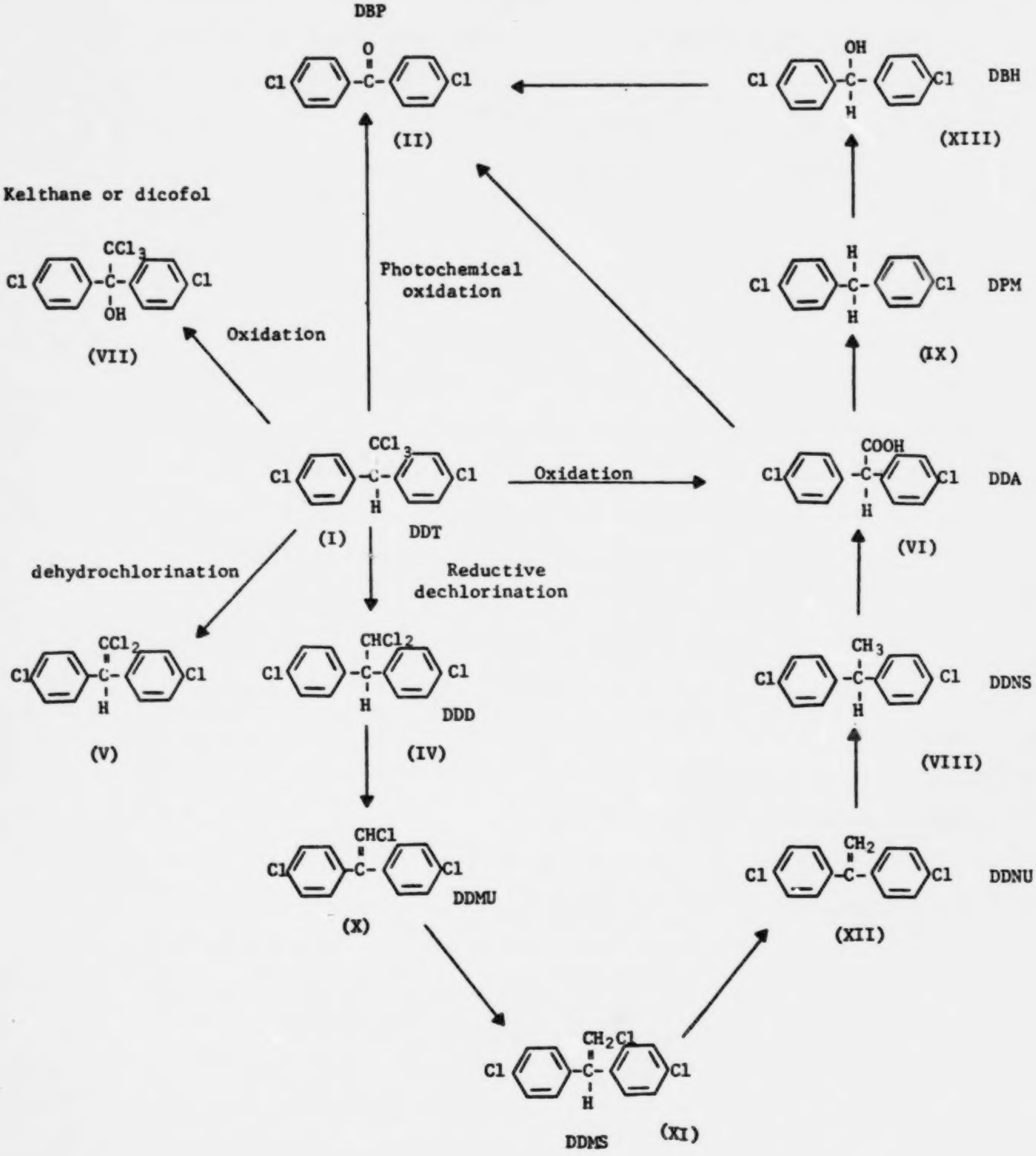
Metcalf, et al.,[60,61] and Harrison, et al.,[62] reported on the behavior of radio-labeled DDT in a model ecosystem to trace the various pathways of translocation and metabolism. The major metabolites noted in the water, snails, mosquitoes, and fish in the ecosystem were DDE and DDD. Residual and accumulated DDT was also found in all. Eberhardt[63] has recently developed a mathematical model for the rate of loss of DDT in water.

The five principal routes of DDT metabolism, reductive dechlorination to DDD, dehydrochlorination to DDE,[64] and oxidation to Kelthane, DBP, or DDA are shown in Figure VII-2 together with the other metabolic routes that lead to the formation of compounds reported to be products of microbial degradation in soil and water environment.

In a recent article, Woodwell, et al.,[64A] discussed the fate and persistence of DDT and the implications to life from the buildup of DDT in the global environment. They concluded that the concentrations in the atmosphere and the mixed layer of the ocean logged by only a few years behind the amount of DDT used annually throughout the world.

FIGURE VII-2

ROUTES OF DDT DEGRADATION AND METABOLISM



DBP
(II)
DBH
(XIII)
Kelthane or dicofol
(VII)
Photochemical oxidation
Oxidation
DPM
(IX)
DDT
(I)
Oxidation
DDA
(VI)
dehydrochlorination
Reductive dechlorination
(V)
DDD
(IV)
DDNS
(VIII)
DDMU
(X)
DDNU
(XII)
DDMS
(XI)

2. The Metabolism and Degradation of Dieldrin

The metabolites and degradation products of dieldrin are shown in Figure VII-3. Although dieldrin is remarkably stable to alkali, it is susceptible to decomposition under irradiation in the ultra-violet region of the spectrum. Photodieldrin, obtained by irradiating dieldrin (2537 Å) in concentrated solution or the solid state is identical with that present in dieldrin-treated grass after exposure to sunlight[7] and has been assigned the structure A by most workers[65,66] although the structure B has also been proposed.[67] It is twice as active as dieldrin against *Musca domestica* and *Aedes aegypti* larvae.[66] Relative to dieldrin, its acute toxicity is higher for rats, mice, guinea pigs, and pigeons, less for domestic fowl and harlequin fish and about equal for beagle hounds.[68] The amounts of photodieldrin formed from dieldrin by sunlight does not significantly increase the overall residues arising from the use of aldrin and dieldrin.[69] Irradiation of dieldrin (A-2537 Å) in dilute hexane solution yields the dechlorinated product (C).[70] C was found to be about five times as active as dieldrin against mice (oral) but less active than dieldrin against *M. domestica*. A number of aquatic microorganisms from silt and water samples taken from Lake Michigan converted dieldrin to photodieldrin.

A number of soil microorganisms have been reported to be active in the degradation of dieldrin. The soil fungus *Trichoderma viride* degraded dieldrin into 4 major metabolites, but only one was unambiguously identified as 6,7-trans-dihydroxydihydroaldrin.[32] *Aerobacter aerogenes* [71] and several other soil microorganisms[72,73] were studied, and it was found that they hydrolyzed dieldrin to at least nine metabolites including 6,7-trans-dihydroxydihydroaldrin (D). Matsumura, et. al.,[74] reported on the breakdown of dieldrin by a *Pseudomonas* species. Five major metabolites were isolated and analyzed. One metabolite was identified as aldrin and the proposed structures for the other four metabolites correspond to E, F, G, & H of

FIGURE VII-3

ROUTES OF DIELDRIN DEGRADATION AND METABOLISM

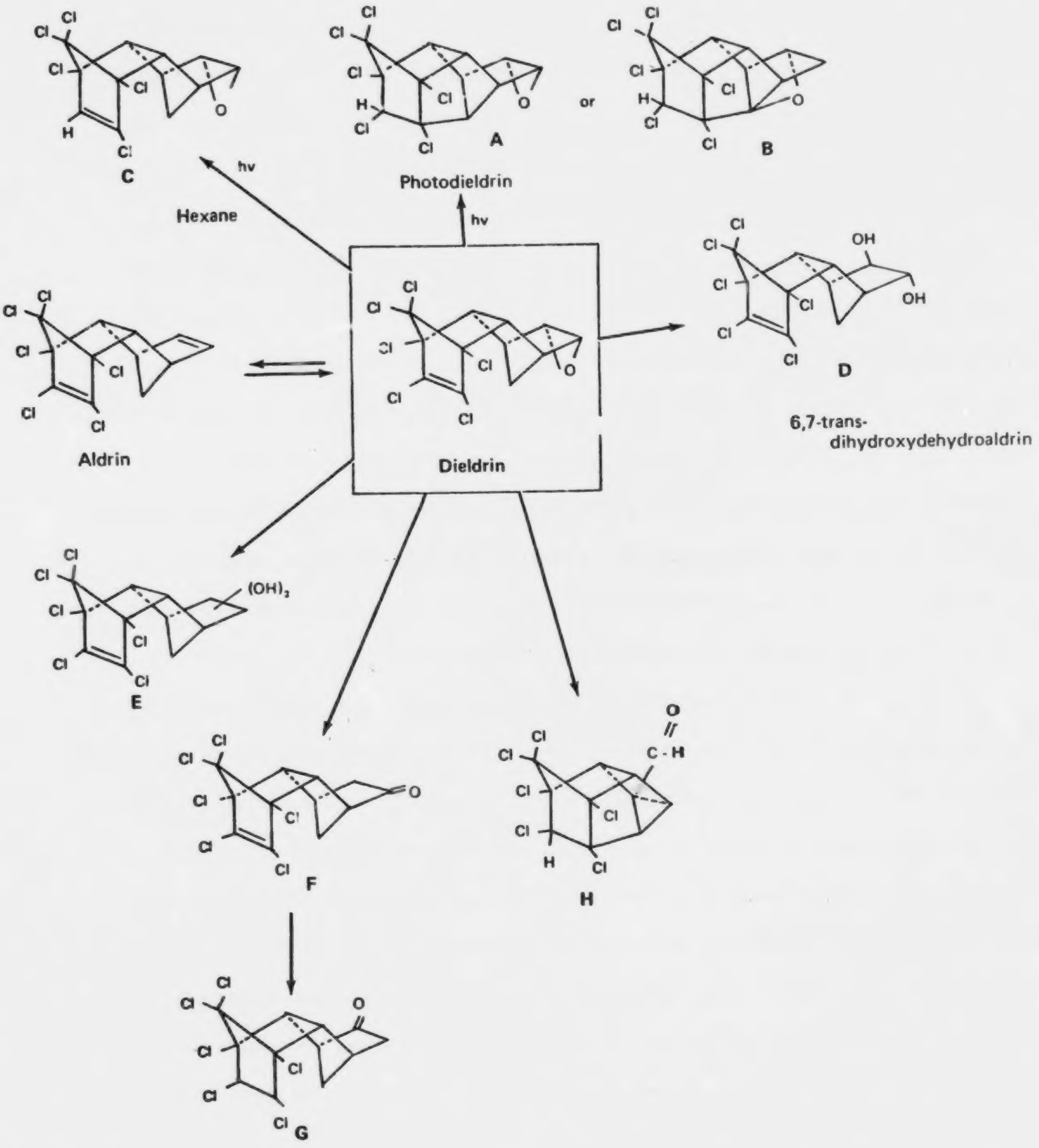

C
Hexane
hv
A
or
B
Photodieldrin
hv
D
6,7-trans-dihydroxydehydroaldrin
Aldrin
Dieldrin
E
(OH)$_2$
F
H
G
Cl
H
O
OH
C-H

Figure VII-3. A larger amount of undegraded dieldrin was also observed with the metabolites. The soil fungus *Mucor alternans* did not degrade dieldrin in pure culture nor in the soil samples.[33] Chacko, et al.,[21] also reported that some soil organisms were incapable of degrading dieldrin.

Dieldrin has been classified as a highly residual compound.[43] The various routes of dieldrin transport in and loss from soils were studied,[75-81] and the major pathways of dieldrin loss were volatilization and sediment transport. However, in both the total and local sense, some residue accumulation can occur and persist.

In a Louisiana estuary, the water, bottom sediment, and oysters were studied to determine the concentration of dieldrin.[82] The data showed that the bottom sediment and the oysters contain 3-4 ppb while the water contains less than 1 ppb, reflecting the insolubility of dieldrin in water.

3. Metabolism and Degradation of Malathion

The metabolism and degradation of malathion is complicated and differs in various animal species, insects, fish or by microorganisms. The possible metabolic breakdown products of malathion are shown in Figure VII-5.

Malathion can be degraded by UV irradiation[83] and gamma radiation[84] but no breakdown products were identified. Kearney[2] quotes reported evidence that malathion in soil cultures was degraded. The reaction appears to be an initial non-enzymatic hydrolysis that gives what was tentatively identified as either α or β - malathion mono-acid. Chen, et al.,[85] reported that only α-malathion monoacid was biologically produced in rats.

Catalytic hydrolysis of malathion in soils to thiomalic acid, dimethylthiophosphoric acid, diethyl thiomalate or diethyl mercaptosuccinate was also reported.[86,78] Konrad, et. al.,[86] reported that malathion degraded in soils occurred by a chemical mechanism catalyzed by adsorption and that diethyl mercaptosuccinate is a degradation product. However, Bowman, et al.,[88] disagreed with these findings and claimed that the evidence of diethylmercaptosuccinate formation is not valid. Instead, they reported minimal degradation of adsorbed malathion on montmorillonite soils over a 3 to 5 day period. Walker has recently reported that malathion is degraded by soil bacteria to malaoxon, malathion monoacid, malathion diacid, dimethylphosphorothioate and dimethyl phosphorodithioate.[89]

The biodegradation of malathion by microorganisms in streams was studied by Randall & Lauderdale.[90] They found that although aeration alone is effective in the degradation of malathion, microbial action is a more effective way of degrading malathion in an activated sludge system. Aerobic microorganisms degraded malathion but no degradation products were identified. Getzin & Rosefield[91] also reported that the heat labile, and alkali-extractable fractions from some soils were capable of degrading malathion within 24 hours. The identity of the breakdown products are still being investigated. Matsumura & Bousch[92] reported that the soil fungus *Trichoderma viride* and a bacteria of the *Pseudomonas* degraded malathion to diethylmalate, demethyl malathion and a carboxyesterase product, the major metabolite. Within 24 hours, the *Pseudomonas* degraded 98% of the malathion applied while the *T. viride* degraded 75 to 90%. These microbial preparations did not convert malathion to its more toxic analog, malaoxon. Lichtenstein, et al.,[93] compared the persistence of organophosphorus pesticides in soils and found that only 5% malathion residues could be recovered from the soil 3 days after application. Malathion was reported to be less stable than parathion and methyl parathion.

The lack of sufficient data on microbial degradation products of malathion led to the consideration of breakdown of products reported in Nigerian beetles,[94] rice brans,[95] maize and wheat grains.[96] Dyte and Rowlands[94] reported that the formation of 0,0-dimethylphosphorodithioate, 0,0-dimethylphosphorothionate, dimethylphosphate, malathion mono-acid and malathion di-acid. Rowlands and Clemente[95] found that in rice brans of high oil and fatty acid content, both dimethyl phosphorothionate and dimethylphosphorodithioate were found while in rice brans of low oil content, the latter was the only metabolite detected.

From studies in maize and wheat grains, Rowlands[96] reported that malathion was degraded to dimethylphosphorodithionic acid (unstable and degrades to phosphoric acid derivatives), malathion mono-acid, and malathion di-acid. These products were formed by chemical and enzymatic hydrolysis. It was also noted that the oxidations of malathion to malaoxon did not occur.

Malathion shows a pattern of metabolic selectivity which probably accounts for the wide differential toxicity between insects and mammals. It has been reported that the metabolism of malathion probably follows two enzymatic routes, i.e., carboxyesterase or phosphatase degradation.[97] The points of degradation and cleavage of malathion are shown in Figure VII-4

In the case where the proper oxidative system is present, malathion is oxidized to malaoxon and then malaoxon can undergo a parallel degradation route, as indicated in Figure VII-5.

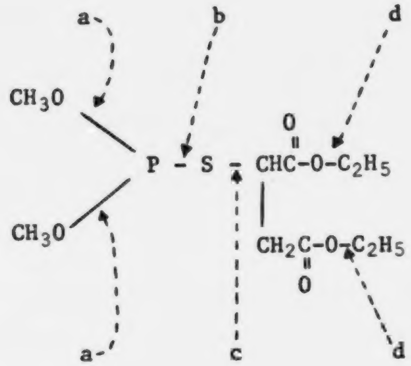
The phosphorus containing metabolites that can be derived from malathion are shown schematically in Figure VII-5.

4. Metabolism and Degradation of Abate

Streams and ponds in California and New Jersey, which have been treated with a total of 1.0 lb of Abate insecticides per acre, were studied to determine the rate of disappearance of Abate. There was no apparent accumulation of Abate in water or mud samples or at sampling stations downstream.[98]

FIGURE VII-4

POINTS OF MALATHION DEGRADATION


a
b
d
CH_3O
O
P - S - CHC-O-C_2H_5
CH_3O
CH_2C-O-C_2H_5
O
a
c
d

Cleavage at point (b) will give diethyl mercapto-succinate which can be hydrolyzed to thiomalic acid.

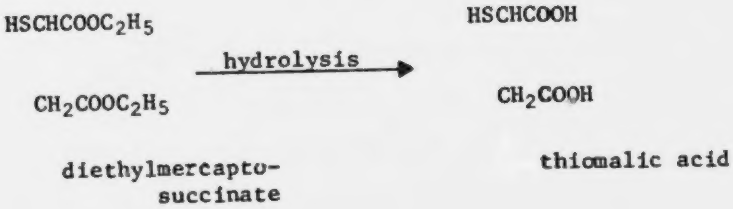
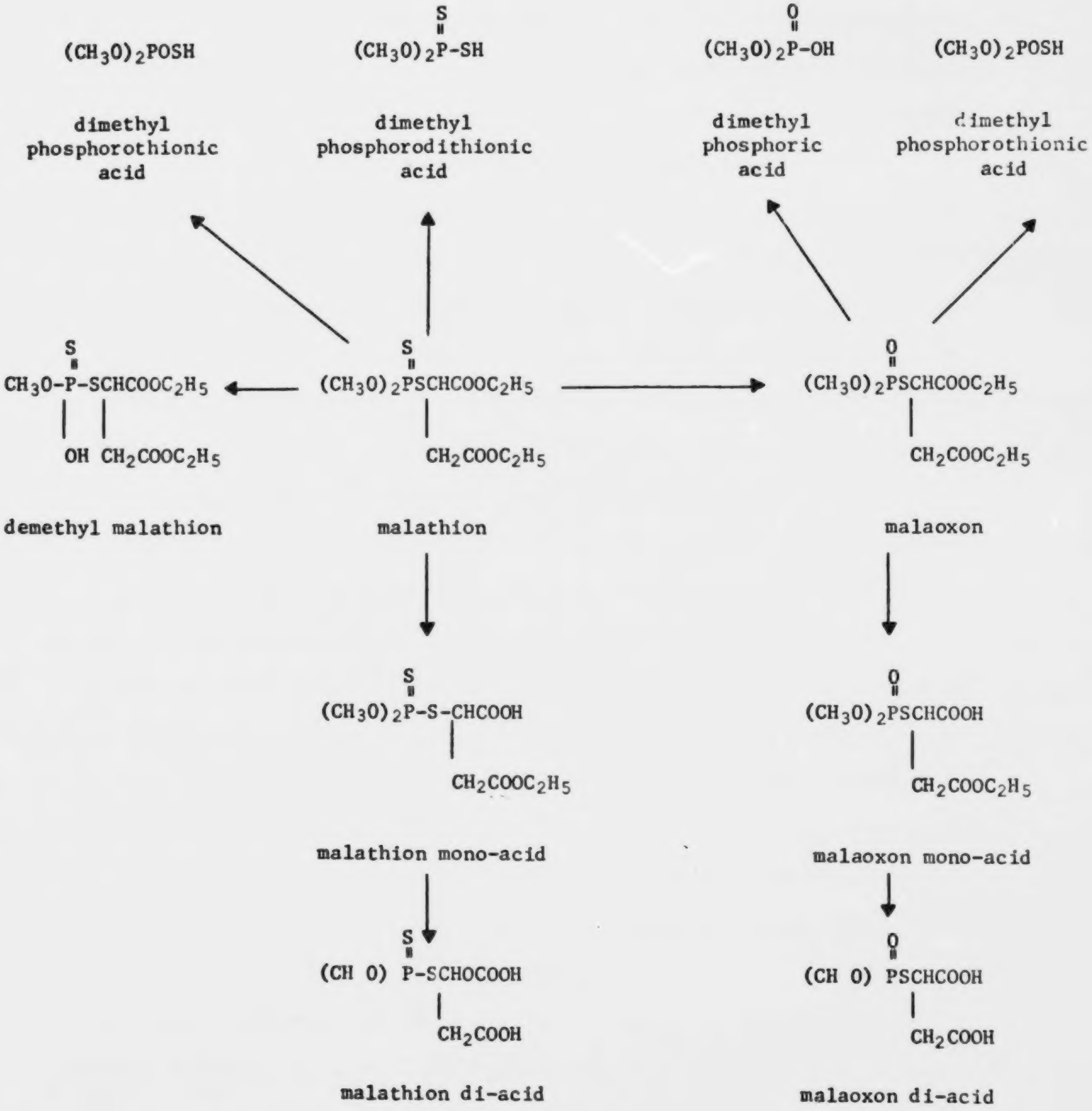

$HSCHCOOC_2H_5$
$CH_2COOC_2H_5$
hydrolysis
$HSCHCOOH$
CH_2COOH
diethylmercapto-succinate
thiomalic acid

FIGURE VII-5

ROUTES OF MALATHION DEGRADATION AND METABOLISM


$(CH_3O)_2POSH$
dimethyl phosphorothionic acid
S
$(CH_3O)_2P\text{-}SH$
dimethyl phosphorodithionic acid
O
$(CH_3O)_2P\text{-}OH$
dimethyl phosphoric acid
$(CH_3O)_2POSH$
dimethyl phosphorothionic acid
S
$CH_3O\text{-}P\text{-}SCHCOOC_2H_5$
OH $CH_2COOC_2H_5$
demethyl malathion
S
$(CH_3O)_2PSCHCOOC_2H_5$
$CH_2COOC_2H_5$
malathion
O
$(CH_3O)_2PSCHCOOC_2H_5$
$CH_2COOC_2H_5$
malaoxon
S
$(CH_3O)_2P\text{-}S\text{-}CHCOOH$
$CH_2COOC_2H_5$
malathion mono-acid
O
$(CH_3O)_2PSCHCOOH$
$CH_2COOC_2H_5$
malaoxon mono-acid
S
(CH O) P-SCHOCOOH
CH_2COOH
malathion di-acid
O
(CH O) PSCHCOOH
CH_2COOH
malaoxon di-acid

There were no reported studies on microbial degradation products, however, studies were reported on the metabolism of Abate in bean leaves[99] and in rats.[100] In the literature search on DDT, dieldrin, and malathion on which studies have been conducted on pesticide metabolism in animals, plants, insects, and by microorganisms, there was a wide overlap on the metabolic products reported. The metabolic routes can vary, but the ultimate end products formed were the same. Thus, perhaps, we can use the reported degradation pathways of Abate in bean leaves and in rats as a working model.

Tritium labelled Abate was used in both studies reported. In the bean leaves, intact Abate was the principal constituent of the residue (70%) indicating a relatively high resistance to degradation. The major degradation products reported were the sulfoxide derivative, and trace amounts of the sulfone derivative, its unsymmetrical mono-oxono analog, and the symmetrical dioxono analog of Abate. The glucosidic conjugates 4,4'-thiodiphenol, 4,4'-thiosulfinyldiphenol, and 4,4'-thiosulfinyldiphenol were also found to increase with time. In rats, where fecal and urinary routes are the major paths of elimination, the feces contained mainly unchanged Abate together with the sulfoxide derivative and the phenolic hydrolysis products while the urine contained mainly sulfate ester conjugates of the phenolic hydrolysis products and trace amounts of unchanged Abate.

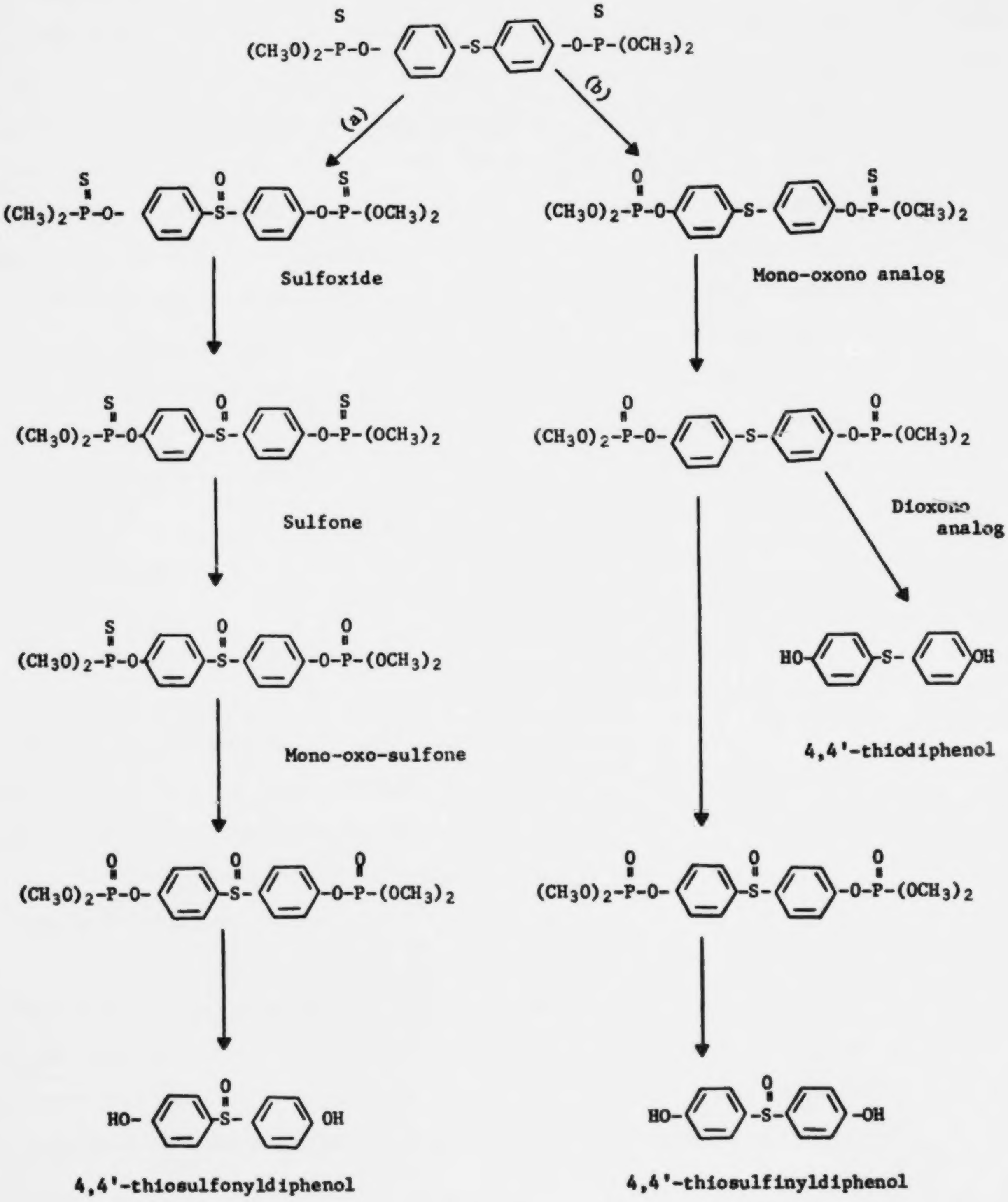
The metabolic route for Abate is shown in Figure VII-6. It appears to follow two routes. Route a is the principal metabolic route. The reaction involves initial oxidation of the sulfide linkage, and subsequent hydrolysis of the phosphate ester groups and glucosidic conjugation of the phenolic hydrolysis products.

C. RESIDUAL LEVELS OF INSECTICIDES

In order to improve our understanding of the residue levels of insecticides that currently exist on Cape Cod, a limited number of samples of bottom mud, soil, and water were taken for pesticide analysis. To do

FIGURE VII-6

ROUTES OF ABATE DEGRADATION AND METABOLISM


(a)
(b)
Sulfoxide
Mono-oxono analog
Sulfone
Dioxono analog
Mono-oxo-sulfone
4,4'-thiodiphenol
4,4'-thiosulfonyldiphenol
4,4'-thiosulfinyldiphenol

this, we chose locations that were near those investigated and described in the biological impact section of this report. Based on their use in past vector control programs on Cape Cod, the insecticides investigated were DDT, dieldrin, and malathion. Abate, which had been used on Cape Cod for vector control up until 1970 at low levels (0.01-0.2 lbs) was not included in the analysis scheme because it was not deemed likely that measureable residues still existed. Also, various fuel oil type formulations were sprayed in the region of interest but these are extremely difficult to distinguish from background oils and were eliminated from the analytical program.

In performing this work, we recognized the desirability of looking for basic chemicals and their degradation products, but our analyses were limited to p,p'-DDT, dieldrin, malathion and the degradation products p,p'-DDE and p,p'-TDE for the following reasons:

- Many of the possible metabolites have not been positively identified and confirmed;
- Easy-to-use analytical procedures are available for only a few of the known metabolites;
- An attempt to establish an approach that would cover all known metabolites would lead to an unweidly analyses scheme which would have been impossible to follow within the budget and time limitations of this project.

The analyses of our samples for pesticide residues were performed by Dr. Karl Deubert of the University of Massachusetts Agricultural Experiment Station at East Wareham, Massachusetts. Dr. Deubert has worked extensively in pesticide residue analysis and some of his unpublished data on residue levels for DDT and dieldrin in salt water and mud at selected sites on Cape Cod has been included in this report as a valuable reference point for our study. Because he already had developed and calibrated the appropriate methodologies for this program, data was available for comparison purposes from previous years. Thus, we were fortunate to be able to take advantage of the prior experience of Dr. Deubert for this program.

It is important to recognize that the data obtained during this program gives a qualitative overview of the current situation but is not under any circumstances to be considered as being statistically significant. To do so would have required the analyses of hundreds of samples--a task which was beyond the present scope of this project. (The reasons for requiring large numbers of samples are related to the wide variabilities and many unknowns when sampling a salt marsh. Some of these are: variations in soil type, whether vegetation roots are included in the sample, and amount of water in the sample.)

All of the evidence available to us from the literature indicated that the levels of organochlorine pesticides and/or organophosphorous compounds should be less than a ppm in the salt marsh areas being studied during this program. Thus, literature values for residues of p,p'-DDT and/or dieldrin in soil samples seldom reach 1 ppm and then only when taken soon after application of the pesticide. In fact, many results were well below 0.1 ppm.[101-103] Earlier results on some mud samples from selected points on Cape Cod had revealed the levels of DDT to be roughly 0.2-0.4 ppm while the levels for dieldrin were 0.01-0.04 ppm.[104] Similarly, the levels of DDT and dieldrin in samples of salt water from marshes on Cape Cod had been less than 1 ppb.[104]

As described in other parts of this report, neither DDT nor dieldrin have been in use for control of mosquitos in salt marshes on Cape Cod since 1966, whereas malathion and/or Abate, two organophosphate insecticides had been applied until 1970. Thus, even though relatively stable, the chlorinated hydrocarbons DDT and dieldrin have not been in use for vector control the past five years and therefore, would not be present in the marsh at high levels due to this use. The organophosphates have been in use for the last few years but are much more rapidly degraded and thus were not expected to be found in the marsh. (It should be noted that as described earlier both types of insecticides--organophosphorous and organochlorine--will degrade to other products. In this study, we attempted to deal only with the well described metabolites of DDT, namely TDE and DDE.) Although not used for vector control purposes, other sources of contamination did exist for each of these pesticides. For instance, dieldrin has been used for pest control in cranberry bogs so that there has been the opportunity for buildup of this pesticide in the Cape Cod area. In addition, many of these pesticides may have been used by pest control operators for a number of different reasons, any of which could have led to a burden on the local environment.

To learn whether the pesticide levels were as low as anticipated, a number of soil and water samples were collected from two areas in the Cape and were analyzed for DDT, TDE, DDE, dieldrin and malathion. The samples were collected on the same day (10/22/71) at the locations shown in Figure VI-1.

1. Experimental

a. Soil Samples

All soil samples were treated by a modification of Shell Chemical Company method PMS 911/67 of 1969 as follows:

A representative sample was placed into an erlenmeyer flask and enough water added to effect a slurry. Two ml of extraction solvent (n-hexane-2 propanol 2:1) were added per gram of sample. Sample sizes ranged from 20-90 g. The samples were shaken vigorously for 20 minutes and then the hexane layer decanted into a separatory funnel. This extraction was repeated twice more and the hexane layer was subjected to the cleanup procedure of Kadoum.[105]

b. Water Samples

Water samples were treated according to the following procedure:

One and a half liters were extracted successively with three 50 ml portions of n-hexane. After clean-up via the procedure of Kadoum,[105] this was then dried over Na_2SO_4 concentrated by evaporation and analyzed via gas chromatography.

c. Gas Chromatography

Gas chromatographic measurements were made on the hexane extracts using the following experimental conditions:

Chromatograph:	Barber-Coleman Model 5360
Column:	Pyrex 6' x 4 mm I.D., 5% QF-1 on 100/120 Varaport 30.
Temperatures:	Column 190°C
	Injector 210°C
	Detector 200°C
Carrier Gas:	N_2, approx. 100 ml per minute.
Sensitivity:	1×10^{-9} amp., att. 2
Voltage:	DC at which 0.5 mg dieldrin causes 25 percent FSD at 1×10^{-9}, att. 2
Recorder:	2 mv

Recovery experiments whereby known amounts of pesticides were added prior to extraction were run at the same time as the samples. These experiments indicated a recovery at 0.1 ppm of 87% for p,p'-DDT, 89% for dieldrin, and 86% for p,p'-DDE.

d. Thin Layer Chromatography

Plates: TLC plates were prepared at a nominal thickness of 0.25 mm using mallincrodt Silic AR TLC-7-6 as the substrate.

Development: N-hexane as solvent in Brinkman sandwich apparatus at 22°C. Development stopped when solvent front had traveled 12 cm.

Visualization: Iodine vapors.

e. General

There are many chemical species which in the analysis procedures can act in a similar manner to DDT, dieldrin and other pesticides. This is because the potential interferring species have similar chemical properties (solubility, reactivity, boiling point, etc.,) and thus are measured in the final readout along with the compound of interest. In developing and utilizing methods for the determination of pesticide residues, analytical chemists take great care to minimize this difficult problem. However, because of the complexity of the situation, compromises must be accepted and a chance for error always exists. There are two ways to effectively reduce this chance for error. One is to build many crosschecks and extra steps into the procedure which makes it too complex and lengthy for routine use. The alternative is to utilize more than one procedure for each sample and thus make the measurement by two completely different approaches. This too adds cost and time to the analysis.

Because of the limited time and budget available for our program, it was impossible to perform the type of confirmatory experimentation which would ensure that all of the data reported here is free from potential interferences. However, reasonable precautions were taken and we feel that our data has the same validity as that found in the published literature.

Nevertheless, it is important to recognize that many analyses for organochlorine compounds are currently being challenged due to the discovery of previously unrecognized interferences and similar possibilities exist for the results reported in the following tables.

2. Results

The results of these analyses are shown in Table VII-1. It can be seen that, as expected, the residue levels were low. (Malathion could not be detected either by gas chromatography or thin layer chromatography in any of the samples. The estimated detection limit for these samples in this analysis scheme was 0.05-0.1 ppm.) Efforts were made to compare sample location and residue level with regard to DDT, DDE, and dieldrin, but no correlation could be found. As noted in Table VII-1, the residue values ranged from <0.001 to 0.09 ppm for DDT and <0.001 to 0.06 for dieldrin with averages of 0.026 and 0.021 ppm respectively.

In addition to the above, four samples taken from surface soil in the marsh, but not directly in a water channel area, showed the following:

Sample		Pesticide Residue (ppm)		
Code	Location	DDT	DDE	Dieldrin
601	Top 4" of sod about 30 yds from Chase Garden Creek (Bass Hole Marsh)	0.03	ND*	0.1
102	0-4" of sod from area north of Rt. 28 bridge (Herring River marsh)	0.1	0.01	0.08
103	4-8" of sod from same location as 102	0.1	0.008	0.09
104	From top of bank of a drainage ditch near location 102	0.01	0.008	0.04

* Not Detectable.

TABLE VII-1

PESTICIDE ANALYSES ON SOIL SAMPLES

Sample Code	Sample Location			Sample Type	Pesticide Found (ppm)*		
	Marsh	Area	Specific		pp'DDT	pp'DDE	Dieldrin
5	Bass Hole	Gray's Beach	Natural Drain into Chase Garden Creek	Bottom Sand	0.02	0.01	0.04
5A	"	"	"	Soil from Bank 2' from Top	0.01	0.004	0.015
6	"	"	Chase Garden Creek Near Above Drain	Bottom Sand	<0.001	ND	<0.001
6A	"	"	"	Soil from Bank 2' from Top	<0.001	0.003	0.006
60	"	White's Brook	Chase Garden Creek	Bottom Mud	<0.001	0.004	0.006
600	"	"	"	Soil from Bank 2' from Top	0.02	0.008	0.009
30	Herring River	South of Rt #28 Bridge	Herring River	Bottom Mud	<0.001	0.001	0.01
301	"	"	"	Soil from Bank 18" from Top	0.07	0.01	0.03
100	"	North of Rt #28 Bridge	Ditch 100 yds NE of River	Bottom Mud	0.04	ND	0.04
101	"	"	"	Soil from Bank 12" from Top	0.04	ND	0.01

TABLE VII-1 (Cont.)

PESTICIDE ANALYSES ON SOIL SAMPLES

Sample Code	Sample Location			Sample Type	Pesticide Found (ppm)*		
	Marsh	Area	Specific		pp'DDT	pp'DDE	Dieldrin
80	Herring River	North Road Near Bell's Neck Rd.	Herring River, NE Buldge Downstream of North Road Bridge	Bottom Mud	0.09	0.02	0.06
801	"	"	"	Soil from Bank 18" from Top	0.01	0.009	0.009
802	"	"	Drainage Ditch Near Above	Bottom Mud	0.004	0.01	0.004
803	"	"	"	Soil from Bank 12" from Top	0.065	0.02	0.06
				AVERAGE	0.026	0.007	0.021
				RANGE	<0.001-0.09	ND-0.02	<0.001-0.06

* ppm = parts per million

ND = not detected

Even though slightly higher, these values do not represent a major significant difference to those in the salt marsh channels.

3. Conclusions

Our results suggested that the insecticide levels in the two salt marshes studied were quite low. Whether they relate to treatment in the past of a "steady state" level due to other causes (spills, atmosphere transport, pickup from the ocean, etc.), or are declining, is not known.

There is some other data available (even though sketchy) which helps to clarify this point. Analyses were made of mud samples in the summer of 1969 and again late in 1971 at four different locations on Cape Cod. These results are given in Table VII-2.[104] It will be noted in comparison with the data in Table VII-1 that the levels of dieldrin in these locations analyzed in 1969 and 1971 are not appreciably different from the values found for 1971 (0.02-0.04 ppm for 1969, and up to 0.06 ppm in 1971). There might be a trend to lower levels in 1971 but significance is questionable.

However, the DDT levels would appear to have decreased by almost a factor of ten (0.2 to 0.026 ppm between 1969 and 1971). Whether this is a real difference or an artifact of the analysis is not known. Additional water samples collected from the same locations in 1969 and 1970 showed higher dieldrin levels by factors of three to ten over those found in water collected under this program in October of 1971. (All levels were extremely low and it would be hazardous to consider this an important and significant finding.) In addition, it is interesting to note that the data for DDT does indicate some differences with possible signs of a trend (see Tables VII-3 and VII-4). Once again, these represent only a limited number of samples so that developing a statistical significance is difficult. Also, a slight modification in the analytical procedure was made between 1970 and 1971 (a QF-1 column was used for the gas chromatography instead of DC-200, and this

TABLE VII-2

ANALYSIS OF MUD SAMPLES

Location of Sample	Pesticide Found (parts per million)					
	DDT			Dieldrin		
	1969		1971	1969		1971
	Sample	Average		Sample	Average	
South Side of Cape - salt pond	0.2 0.2 0.4	0.3	0.01	0.02 0.02 0.09	0.04	0.001
Same pond, different location	0.2 0.3 0.2	0.2	0.04	0.03 0.04 0.02	0.03	0.03
Same pond, different location	0.3 0.3 0.1	0.2	0.03	0.03 0.02 0.02	0.02	0.007
Creek on Upper Arm of Cape	0.02 0.3 0.3	0.3	0.08	0.03 0.03 0.06	0.04	0.007
River on Upper Arm of Cape	0.2 0.3 0.2	0.2	0.02	0.02 0.02 0.03	0.02	0.003
Creek on Upper Arm of Cape	0.2 0.2 0.2	0.2	0.01	0.04 0.03 0.06	0.04	0.009
AVERAGE		0.2	0.03		0.03	0.02
RANGE		0.2-0.3	0.01-0.08		0.02-0.04	0.001-0.07

TABLE VII-3

ANALYSIS OF WATER SAMPLES (1971)

Date	Code	Location	Pesticide Found (ppb)* DDT	Pesticide Found (ppb)* Dieldrin
10/71	5	Bass Hole Marsh - Drain into Chase Garden Creek	0.01	0.01
	6	Bass Hole - Main Channel of Chase Garden Creek	0.005	0.005
	3	Herring River - Main Channel	0.005	0.005
	10	Side Ditch 100 Yards from Herring River	0.005	0.005
	8	Herring River - Main Channel	0.005	0.010
		AVERAGE	0.006	0.008

* ppb = parts per billion

TABLE VII-4

PESTICIDE LEVELS IN SELECTED WATER SAMPLES

		Pesticide Levels Found (parts per billion)*							
		DDT				Dieldrin			
		1969		1970	1971	1969		1970	1971
Code	Location	Range	Average			Range	Average		
A	Pond on South Side of Cape	0.07-0.4	0.3	0.09	0.006	0.01-0.04	0.02	0.02	0.006
B	Same Pond - Different Location	0.04-0.4	0.2	0.2	---	0.01-0.04	0.03	0.02	---
C	Same Pond - Different Location	0.04-0.4	0.2	0.1	---	0.01-0.06	0.03	0.05	---
D	Creek on North Arm	0.01-0.07	0.3	0.1	0.009	T -0.07	0.02	0.009	0.01
E	River on North Arm	0.01-0.8	0.2	0.1	0.005	0.01-0.09	0.04	0.04	0.008
F	Creek on North Arm	0.04-0.8	0.3	0.09	0.005	T -0.05	0.02	0.06	0.004
	AVERAGE		0.25	0.1	0.006		0.03	0.03	0.007

---

* T = trace.

may account for the differences. However, it seems appropriate to recognize that this trend might be real. In this regard, Woodwell, et. al.,[64A] recently concluded that DDT levels in the biosphere are slowly decreasing from their maximum levels which occurred in the mid-1960's as a result of the widespread use of DDT during that period. Our data from work conducted in Cape Cod salt marshes suggests that DDT levels have decreased between 1969 and 1971 and tends to support the Woodwell conclusions.

In any case, in order to determine whether these interesting tentative observations are valid would require a much more comprehensive program whereby more samples could be examined in greater detail so that conclusions which were statistically sound could be reached.

D. GLOSSARY OF TERMS

1. Insecticides

Dieldrin - 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-exo-5,8-dimethanonaphthalene.

Malathion - 0,0-dimethyl S-(1,2-dicarbethoxyethyl)phosphorodithioate.

Abate - 0,0,0',0'-tetramethyl 0,0'thiodi-p-phenylene phosphorothioate.

2. DDT. Metabolites

DDT - 1,1,1 trichloro - 2,2-bis (p-chlorophenyl) ethane.

DDD (TDE) - 1,1-dichloro - 2,2-bis(p-chlorophenyl) ethane.

DDE - 1,1-dichloro - 2,2-bis (p-chlorophenyl) ethylene.

DDMU - 1-chloro - 2,2-bis (p-chlorophenyl) ethylene.

DDMS - 1-chloro - 2,2-bis (p-chlorophenyl) ethane.

DDNU - 2,2-bis (p-chlorophenyl) ethylene.

DDNS - 2,2-bis (p-chlorophenyl) ethane.

DDA - bis (p-chlorophenyl) acetic acid

DBP - 4,4'-dichlorobenzophenone.

Dicofol - 1,1,1 trichloro - 2,2-bis (p-chlorophenyl) ethanol.

DPM - bis (p-chlorophenyl) methane.

DBH - bis (p-chlorophenyl) methanol.

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VIII. LAWS AND REGULATIONS GOVERNING PESTICIDES

A. FEDERAL REGULATION OF PESTICIDES

1. Organizations

a. Environmental Protection Agency

The Environmental Protection Agency (EPA) has responsibility for establishing and enforcing pesticide standards, for monitoring and analyzing the environment, for conducting research and demonstrations related to the environment and assisting state and local governments in establishing and carrying out pollution control programs. It is responsible for carrying out anti-pollution policies and executing many of the tasks necessary to effectively control pollution from all sources.

The EPA combined the major federal pollution control programs previously located in five separate federal agencies. These included the Federal Water Quality Administration from the Department of the Interior (Interior); the National Air Pollution Control Administration, The Bureau of Solid Waste Management, Bureau of Water Hygiene, and Bureau of Radiological Health from the Department of Health, Education and Welfare (HEW); pesticides standards and research from HEW and Interior; pesticides registration from the Department of Agriculture; the Federal Radiation Council from the Executive Office of the President; and environmental radiation standards from the Atomic Energy Commission.

b. Department of Health, Education and Welfare

The Department of Health, Education and Welfare has responsibility under the Federal Food, Drug and Cosmetic Act for monitoring and enforcing standards for pesticides in or on agricultural commodities and processed food but EPA establishes these standards. The Department is also responsible for protecting the public from occupational and environmental hazards and from other public health problems including diseases transmitted by vectors.

c. Department of Agriculture

The Department of Agriculture is responsible for research on the effectiveness of pesticides and for various other research, information, education, and regulatory programs to protect human beings, crops, livestock, forests, stored products, and structures against insects, weeds, fungi, and other pests.

d. Department of the Interior

The Department of the Interior is responsible for the conservation of wild birds, fish, mammals, and their food organisms in the environment, and it is generally responsible for research on all factors affecting fish and wildlife. However, authority for research to determine the specific effects of pesticides on birds, fish, and other wildlife rests with EPA.

e. Other Organizations

There are numerous other federal government organizations which influence the use of pesticides for vector control. These include the Federal Working Group on Pest Management, Hazardous Materials Advisory Committee, Armed Forces Pest Control Board, the Interior Intra-departmental Pesticides Working Group, and the Agriculture Intra-departmental Pesticides Working Group.

2. Federal Legislation

Federal laws that most directly deal with the use, sale, transportation, and application or effects of pesticides and other hazardous substances include the following:

a. Water Quality Improvement Act, P.L. 91-224, 84 Stat. 91 (1970).

b. Environment Quality Improvement Act, Public Law 91-224, 84 Stat. 114 (1970).

c. Clean Water Restoration Act, P.L. 89-733, 80 Stat. 1246 (1966).

d. Water Quality Act, P.L. 89-234, 79 Stat. 903 (1965).

e. Federal Water Pollution Control Act, P.L. 87-88, 75 Stat. 204 (1961).

f. Water Pollution Control Act, P.L. 84-660, 70 Stat. 498 (1956).

g. Water Pollution Control Act, P.L. 82-579, 66 Stat. 755 (1952)

h. Water Pollution Control Act, P.L. 80-845, 62 Stat. 1155 (1948).

i. Fish and Wildlife Coordination Act, P.L. 85-624, 16 USC 661 (1958).

j. Federal Insecticide, Fungicide, and Rodenticide Act, 7 USC 135, 61 Stat. 163 (1919).

Important executive orders dealing with pesticides or their effects include:

- Executive Order 11507-Prevention, Control, and Abatement of Air and Water Pollution at Federal Facilities, 4 February 1970.

- Executive Order 11288-Prevention, Control and Abatement of Water Pollution by Federal Activities, 2 July 1966.

These laws and executive orders, when coupled with executive regulations and procedures, constitute the national framework within which vector control programs are undertaken in the northeast states.

3. Federal Cases

Several pesticide cases have been heard that involve federal law or federal agencies or officials in recent years. To date, these cases have mostly dealt with procedural issues. For example, in Nor-Am v. Hardin, 1 ER 1460 (USCA 7th) the court held that the --

> Manufacturer of mercury fungicide, use of which was ordered suspended by Secretary of Agriculture under Federal Insecticide, Fungicide and Rodenticide Act, 7 USC 135, based on a single abnormal incident and without a hearing, was entitled to federal court review on a claim that the order was arbitrary and capricious, since the order was the final determination of the matter of imminent hazard to the public.

Other important cases are Environmental Defense Fund v. HEW, 1 ER 1341 (USCA, DC) and Environmental Defense Fund v. Hardin. 1 ER 1347 (USCA, DC).

B. MASSACHUSETTS REGULATION OF PESTICIDES

1. Organizations

a. Pesticide Board

The Commonwealth of Massachusetts established a Pesticide Board in the Department of Public Health in 1962. The members of the board are the Commissioners of Public Health (Chairman), Natural Resources, Agriculture, and Public Works, the Director of the Division of Fish and Game and the Chairman of the State Reclamation Board or their designees, and five members appointed by the governor. The appointive members serve for terms co-terminous with the governor.

The board may adopt and make provisions to enforce such rules and regulations as it determines are necessary to protect the public interests in the soils, waters, wetlands, wildlife, agriculture, and other natural resources of the Commonwealth. It is also to undertake a continuous study of methods of applying and using pesticides, the effects of such applications and uses, and to publish the results of this work from time to time.

Upon written request from the Pesticides Board, its financial needs are included by the Commissioner of Public Health in the budget of the Department of Public Health.

The board is required to meet at least four times per year and may also meet when called by the Chairman or upon written request by any two members. Board decisions are rendered by a majority vote and implemented by the Commissioner of Public Health. However, other governmental agencies, when authorized by the board in writing, can carry out certain provisions of the law and the rules and regulations promulgated by the board.

b. Reclamation Board

The Commonwealth of Massachusetts established a State Reclamation Board under Chapter 252 of its General Laws. The members of the board are one employee of the Department of Public Health, one employee of the Department of Agriculture, and a third member designated jointly by the heads of both departments. These members must be approved by the governor and the Governor's Council. The board is under the administrative control of the Department of Agriculture.

The board is to make determinations of the usefulness and necessity of improving lowland by draining or removal of obstructions in streams or rivers, and the necessity of eradicating mosquitoes in any infested area. The board is to consider the agricultural or industrial uses made possible on such land, the protection of the public health, the utilization of any deposits in such land, and other purposes made possible by any proposed treatments.

c. Water Pollution Control Division, Massachusetts Department of Natural Resources

The Commonwealth of Massachusetts established a Water Pollution Control Division under the control of the Water Resources Commission in the Department of Natural Resources under Chapter 21 of the General Laws as amended in 1966, 1967, 1969, and 1970. The division has a director appointed by the commission and its work is supervised by the commission. The director employs an assistant director, division legal counsel, and other necessary professional, technical, and clerical personnel, subject to the approval of the commission.

The division's responsibilities are to establish programs for the prevention, control, and abatement of water pollution and to otherwise enhance the quality and value of the water resources of the Commonwealth. Among its responsibilities, as cited in the law, are the establishment of water quality standards, periodic examination of water quality, and the submission of proposed water pollution abatement districts, with the approval of the commission, to cities and towns. Such districts are established after approval by those in the area proposed for inclusion in the district and each becomes a body politic and corporate with a governing district commission.

Also, under the law, the members of the Water Resources Commission and the Commissioner of the Department of Public Safety sit as a board to control the handling and disposal of certain chemical and hazardous wastes.

The board, after public hearing, may adopt rules and regulations to protect the public and the environment from the effects of handling and disposal of such chemicals and wastes. The law states that these responsibilities are not to diminish or interfere with the responsibilities of any other agency.

2. Massachusetts Laws, Regulations, and Regulatory Processes

a. Hazardous Substances Act, Chapter 94B (1960)

The Hazardous Substances Act places the responsibility for control of hazardous substances in the Department of Public Health under the direction of the commissioner. The commissioner may formulate reasonable rules and regulations declaring any substance to be hazardous when he finds it satisfies the definition set out by the law.

(1) Registration. Every pesticide distributed, sold, offered for sale in the Commonwealth, delivered for transportation or transported in intrastate commerce, or between points within the Commonwealth through any point outside the Commonwealth, must be registered with the Director of the Food and Drug Division, and such registration must be renewed annually.

The registrant files with the commissioner a statement including his name and address, and the name and address of the person whose name will appear on the label; the name of the pesticide; a complete copy of the labeling for the pesticide and a statement of all claims to be made for it, including directions for use. If requested by the commissioner, a full description of the tests made and their results must also be filed.

It is unlawful to distribute, sell, or offer for sale in the Commonwealth or to deliver or transport any pesticide not registered, or for which different claims are made or for which the composition differs from that set out in connection with its registration. The commissioner has the authority to revoke or modify any registration granted under Chapter 94B if the Pesticide Board finds that continuation of the registration would constitute a hazard to the public health, fish, wildlife, shellfish, or other natural resources of the Commonwealth. When such a claim is made, the commissioner notifies the registrant in writing of the effective date of the revocation of the registration. An appeals procedure is available to the registrant.

(2) Labeling. Pesticides must be labeled with the name and address of the manufacturer, registrant, or person for whom it was manufactured, the name, brand, or trademark under which the substance is sold, the net weight, and the measure of the content. Any pesticide which contains a substance highly toxic to man must be labeled with a skull and crossbones and the word "poison" prominently in red on a background of contrasting color, and the antidote.

The act prohibits any alteration of the label on a hazardous substance while any portion of the substance is still in the container and makes it unlawful to receive or deliver a misbranded package containing a hazardous substance. A hazardous substance in a container used for food, drug, or cosmetics and still bearing its regular label cannot be sold or given away. Any such use of containers results in the hazardous substance being misbranded. A misbranded package, when manufactured with the intent that it be distributed or sold, is to be embargoed by a representative of the Division of Food and Drugs and submitted to the jurisdiction of the courts, except when intended for export to any foreign country and labeled according to the laws of the foreign country and to show that it is intended for export.

(3) Enforcement. The commissioner and his designees are authorized to make inspections to enforce the provisions of Chapter 94B and any rules and regulations the commissioner promulgates under that chapter. They are to have access at reasonable times to any premises where they suspect the presence of any hazardous substance that is misbranded.

Persons manufacturing, storing, receiving, or holding hazardous substances are to provide the director or his inspectors with access to all records showing any movement or holding of such substances during or after movement, and the quantities involved and are to allow these records to be copied.

Any person who obstructs the director or his inspectors from entering premises where hazardous substances are kept or does not comply with the provisions for providing for records and copying is subject to punishment by a fine of not more than $2000 or imprisonment of up to six months or both.

The commissioner may authorize formal complaints to appropriate authorities or the superior court where it appears that any provisions of the pesticides law were violated. Except for special provisions in the case of certain violations of the law, a first offense is punishable by a fine of not less than $150 or more than $200. For a second or subsequent offense, the fine is not less than $200 or more than $1000, or imprisonment of not more than 90 days, or both.

(4) Licenses for Pesticide Sales. No wholesaler or distributor other than a person selling at retail level may sell, offer to sell, distribute, or deliver a pesticide in the Commonwealth unless he has a license to do so from the Department of Public Health. Such licensees are to supply the Pesticide Board with information concerning the quantities of certain pesticides, the use of which has been regulated by the board or which are being considered for regulation, that were sold or delivered in the Commonwealth and the names and addresses or such purchasers or recipients upon the board's request.

(5) Appeals and Administrative Procedures. The law sets out procedures for correcting any discrepancies in labeling or claims for a pesticide and for formally challenging decisions made by the commissioner.

(6) Embargo. Any pesticide which is adulterated or misbranded or which has not been registered under the provisions of Chapter 94B or which does not bear on its lable the information required by the pesticide law, or which is a white powder pesticide, and not colored as required by the pesticide law can be embargoed.

(7) Pesticide Board. The duties and powers of the Pesticide Board are defined in the act.

In general, the power delegated to the Pesticides Board to control application and use of pesticides is broad. The board can adopt and amend regulations controlling the storage, transportation, use, and application of pesticides that it deems necessary for protecting public health and public interests in the environment. Before adopting these regulations, however, the law requires that the board consult with the scientific community, the pesticide industry, pesticides applicators and users, and the general public.

The board is restricted from requiring farmers or persons applying pesticides on or under any structure to be licensed but these persons may be required by the board to design a statement pledging to use pesticides only as authorized by the board. The law provides that anyone using an aircraft to apply pesticides must be licensed.

Violators of the rules and regulations issued by the board are subject to a fine up to $100 for the first offense and a fine of up to $500 for subsequent offenses.

The Pesticides Board adopted rules and regulations on March 12, 1964, and amended the same on March 29, 1967; May 13, 1971; and May 26, 1971. The rules and regulations require the restriction of all pesticides used or applied in the Commonwealth to be registered with the Division of Food and Drugs, Department of Public Health. Each pesticide is registered in terms of uses, rates of application, and intervals of use, and the regulations require that any pesticide will be used only for registered uses and will not exceed registered dosages and intervals.

All uses of pesticides on surface, near subterranean, or in the watershed area for public water supplies must be approved by the board upon the recommendation of the Department of Public Health.

Disposal of pesticides is to occur only in a disposal area assigned by local boards of health and operated according to relevant Massachusetts laws, in municipal incinerators, or in other devices approved by the Department of Public Health. If the materials are disposed of by burial, such disposal must insure that contamination of ground or surface water is held to a minimum and that the materials will not be disturbed by subsequent activities in the area.

Burning of certain pesticides is authorized if the local fire department is contacted and if in compliance with regulations of local boards of health or the Metropolitan Air Pollution Control District.

Methods of disposal of pesticides containers are not specified in the board's regulations, but instead fall under rules and regulations established by the Department of Public Health. Treatment of pesticides containers prior to their use for limited purposes is also regulated by the Department of Public Health.

Persons applying or handling pesticides are individually responsible for their own safety and safety procedures.

Any application of pesticides to the land of another must be made in the presence of a person licensed by the board. Requirements for licensing include experience at the operational level of pesticides application under a person holding a supervisory license or such experience in combination with specified educational qualifications and successful completion of an examination conducted under the direction of the board. Licenses are issued for a two-year period or temporarily, at the discretion of the board.

Non-residents may apply pesticides in the Commonwealth if they are licensed in another state under a law requiring similar qualifications of the licensee and if the other state grants reciprocity to applicators licensed in Massachusetts.

At least one supervisory license is required for each business and governmental entity that applies pesticides to the land of another. A supervisory or operational licensee must be present wherever and whenever pesticide applications are made.

The board may suspend or revoke any license granted under its regulations following a hearing before the board if it is demonstrated that the licensee failed to observe any board rule or regulation or any law relating to pesticides.

Pesticide applications by licensed persons from aircraft must be reported to the board within seven days. All other applications by licensed persons must be recorded so that, upon request of the board, the following data may be made available: area treated, pesticide formulation used, dosage applied, method of application, date(s) of application, target organisms, persons licensed by the board who planned and executed the application, and any difficulties encountered which may have produced hazards.

The Pesticide Board has acted to regulate the use and application of certain pesticides as follows:

> ...pesticides (1) which are persistent in the environment; (2) which accumulate as the pesticide per se or its metabolites or degradation products in plant or animal tissue or products and which may be transferred to other forms in life; (3) which are translocated from the point of application to points where they do not serve a useful

> purpose, and (4) which by virtue of this persistence, accumulation or translocation create a risk of harmful effects on organisms other than the target organisms, or other pesticides with regard to which the board finds that regulation is necessary in order to protect the public wealth and the public interests in the soils, waters, forests, wetlands, wildlife, agriculture and other natural resources of the Commonwealth. It is the intention of the Pesticide Board to repeal any use permitted herein when feasible non-persistent substitutes for these pesticides and uses become available.

The board has ruled that DDD (TDE), aldrin, endrin, heptachlor, and marine-fouling paints which contain the substance mercury in any form or compound cannot be used or applied in Massachusetts. It has restricted the use and application of dieldrin, chlordane, BHC, 2,4,5-T, DDT, and toxaphene. Of these pesticides, dieldrin, 2,4,5-T and DDT cannot be used or applied without a permit from the board and then only subject to any restrictions set out in the permit. Such a permit must be displayed before these pesticides can be purchased.

The Chairman of the Pesticide Board may issue a permit allowing the limited application of restricted pesticides to control dangers to the public health, a recently introduced pest, or where there is demonstrated public necessity for their use.

b. Mosquito and Greenhead Fly Control, Ch. 252 (1929)

(1) The Legal Framework. The Chapter 252 authorizes the Reclamation Board to undertake activities to improve lowlands and to control mosquitoes and greenhead flies. The board may authorize improvement activities only if state or local governmental entities and/or individual proprietors petition the board to allow improvements that will help attain the objectives cited in the law. If the proposed improvements appear advisable to the board, it must give public notice of the petition and the

date of the hearing before the board. If there are no individual proprietors involved in the petition, and the board determines that the improvements should be undertaken, the construction and maintenance of the proposed improvements are undertaken without the formation of a reclamation district. Instead, all persons and governmental entities benefited by the project are notified by the board as to the estimated expenses and maintenance costs for the project. Upon receipt of adequate funds, the board appoints one or more commissioners and authorizes them to carry out and maintain the improvements.

If the individual proprietors have joined in the petition, the board, after determining that the proposed improvements should be undertaken, must decide whether to organize a reclamation district to carry out and maintain the improvements. If it decides that a district should be organized, it appoints commissioners and authorizes them to form a reclamation district and to carry out and maintain the improvements.

A reclamation district is formed by the newly sworn commissioners by calling a meeting of the owners of the land to be improved, indicating the matters upon which action is to be taken at the meeting. A majority of interest in value or area, including valid proxies, is required for the meeting to act. If such majority is present, the meeting may vote on whether to accept Sections 1 through 14B of Chapter 252 of the General Laws of the Commonwealth of Massachusetts (the law governing the Reclamation Board and reclamation districts) and whether to create a reclamation district. The structure, officers, and operation of reclamation districts are set out in the various sections of Chapter 252 of the General Laws.

Mosquito abatement may be undertaken in any manner approved by the Reclamation Board by the Board of Health of a city or town not included in an improvement program area under the Reclamation Board or by the commissioners of a mosquito control project established under the Board. Prior to undertaking such abatement procedures, the owners of the area where the procedures will be undertaken must be notified in the newspaper published in the town where the area is situated. The notice must indicate the time and place of a public hearing on the abatement program. At the hearing, the Board of Health or the commissioners must hear all interested parties.

An owner of any part of the area where the abatement program will be undertaken can appeal the decision to carry out the program to the county commissioners within 14 days after the hearing conducted by the Board of Health or the commissioners. The commissioners shall hear the petitioner(s), the Board of Health or commissioners, and the Reclamation Board or its agent within 14 days after receipt of the appeal. If the county commissioners do not decide within two weeks that the abatement is not required, then it may proceed. Any person who suffers property damage by any work undertaken for mosquito abatement purposes may recover his damages according to law from either the city or town undertaking the project or from the county or counties in which any city or town included in the project is located when such work is undertaken by commissioners appointed by the board.

(2) Development of Vector Control Programs. The State of Massachusetts has eight mosquito abatement districts, six of which are set up under separate legislative acts--the other two come under Chapter 252

of the General Laws. The history of vector control in Massachusetts can be traced back to 1870 or 1880 when the town of Belmont did the first mosquito program to control malaria before the malaria cycle was actually worked out. The next step was taken in Cape Cod where local people financed a number of private and municipal attempts around 1920 to control mosquitoes, including the spraying of oil over standing water on the marsh lands.

In 1928 the Cape Cod Chamber of Commerce organized a countrywide fund-raising drive to raise funds for mosquito control. In these years, it was very obvious that the prevalence of mosquitoes on Cape Cod could prevent the area from becoming one of the leading recreational areas in the East. The fund-raising committee obtained $200,000 and helped establish the Cape Cod Mosquito Control Project.

In 1929, in an amendment to the Chapter 252 through Chapter 288, mosquito control is mentioned for the first time in the laws of Massachusetts. Under this chapter, authority is given to towns and cities for the improvement of lowlands and swamps and the eradication of mosquitoes. In 1930, legislation was enacted creating the Cape Cod Mosquito Control Project by Chapter 379. Upon enactment of this legislation, the first mosquito control project in the state came under the direction of the State Reclamation Board within the Department of Agriculture.

During the middle and early thirties, considerable ditching throughout the coastal area of the state was performed by the Works Progress Administration (WPA) which made personnel available for marsh work. Afterwards, the individual cities and towns financed the maintenance of such works through the State Reclamation Board.

The second mosquito control project was created by Chapter 456 of the Acts of 1945 in Berkshire County. This is the only district not in the eastern part of the state.

In 1956 the Norfolk Mosquito Control district was created by Chapter 341. The creation of a number of other districts immediately followed. In the same year the Bristol County District was created by Chapter 506, the Duke County by Chapter 371 (although this project never materialized because four out of the six towns included in the district withdrew shortly after they were entitled to organize). Plymouth County was organized in 1957 and Essex County in 1958. The Essex project did not begin operating until 1964 because sufficient funds were not made available.

There are also two other mosquito control projects in the State of Massachusetts, the voluntary projects of East Middlesex and South Shore. Although not created by legislative acts, they have been in effect for some time under the general supervision of the Reclamation Board.

In 1948 a law was enacted establishing greenhead fly control projects. Work was performed under the direction of the Executive Secretary of the State Reclamation Board. Essex County and Cape Cod formed control districts while the South Shore performed the works as a voluntary project. For those towns and cities that have set up as a reclamation district, the state government pays one-third of the total cost of greenhead fly control and the remaining two-thirds is financed by the individual cities and towns. If a district is not established the communities bear the entire cost of the program.

The Cape Cod Greenhead Fly Control District was administered under the Mosquito Abatement Project, and the Essex County District and South Shore project were also turned over to the Mosquito Abatement districts after their creation.

The mosquito and greenhead fly control projects are all under the direction of the State Reclamation Board. The Board appoints the district commissioners who are in charge of managing the vector control project. The commissioners hire a superintendent and all other necessary personnel for the proper conduct of the project.

The projects are financed by the individual towns who are members of the district. The appropriations, which are established under the legislative acts for each district, are based on the assessed value of the town or area real estate as established by the State Treasurer. In the voluntary projects of South Shore and Middlesex, the appropriation is made annually at a town meeting and is subject to variation from year to year. The district funds are deposited with the State Treasury Office and as the districts incur expenses they send the bills to the Reclamation Board for approval. The Board in turn sends it for payment to the comptroller's office.

In addition to abatement districts, individual towns take upon themselves from time to time mosquito control projects which sometimes overlap with district abatement programs.

c. Massachusetts Clean Waters Act--Chapter 21 (1966)

The Division of Water Pollution Control has the following responsibilities under the law:

(1) To encourage the adoption and execution by cities, towns, industries, and other users of waters in the Commonwealth and by cooperative groups of municipalities and industries, of plans for the prevention, control, and abatement of water pollution.

(2) To cooperate with appropriate federal agencies or agencies in other states and with interstate agencies in matters related to water control quality. The division shall also cooperate with and assist departments, boards, officials, and institutions of the Commonwealth or its political subdivisions that are concerned in any way with the problems of water pollution.

(3) To conduct a program of study, research, and demonstration by itself or in cooperation with other governmental agencies relating to new and improved methods of pollution abatement and more efficient methods of water quality control.

(4) To adopt standards of water quality applicable to various waters or portions of waters in the Commonwealth and a plan for implementation and enforcement of those standards. Standards that relate to the public health shall be adopted only with the written approval of the Commissioner of Public Health.

(5) To examine periodically the water quality of various coastal waters, rivers, streams, lakes and ponds in the Commonwealth and to publish the results of such examinations together with the standards of water quality established for said waters.

(6) To prepare and keep current a comprehensive plan which shall be approved by the Water Resources Commission for the abatement of existing pollution and the prevention of further pollution of the waters of the Commonwealth.

(7) To arrange for personnel engaged in water pollution prevention and abatement to take courses designed to instruct them in methods of water pollution control.

(8) Adopt, amend, or repeal after hearing and with the approval of the Water Resources Commission, rules and regulations necessary to properly administrate the laws relative to water pollution control and for the protection of the quality of water resources.

(9) To require submission for approval of reports and plans for abatement facilities and to inspect such facilities to assure their compliance with the approved plans.

(10) Undertake immediately whenever there is spillage, seepage, or other discharge of oil into any of the waters of the Commonwealth or any offshore waters which may result in damage to the water shores or natural resources of the Commonwealth, to contain or remove such oil.

The division is authorized under the law with the approval of the Water Resources Commission to propose water pollution abatement districts consisting of more than one city or town for the purposes set forth in the law. The division is to supervise the operations and maintenance of any facilities of the pollution abatement district and the director may require the district commission to take such immediate action as may be necessary to maintain the required standards.

The Director of the Division of Water Pollution Control is to provide for the conduct of research and for demonstration projects related to water pollution control.

The director or his authorized representative may at reasonable times enter upon any public or private property to investigate or inspect any condition related to the pollution or possible pollution of any waters and may make such tests as are necessary to determine the source of pollution. The director or his authorized representative may also examine any records or papers pertaining to the operation of any disposal system or treatment works.

The law provides for a fine of not more than $1000 for anyone who directly or indirectly throws, drains, runs, or discharges into the waters of the Commonwealth organic or inorganic matter which causes or contributes to conditions in contravention of the water quality standards adopted by the division. Each day the violation continues is a separate offense and punishable by a similar fine. The director is to notify the person making or permitting such discharge in writing and order the person to correct the condition or complaint according to a schedule included in the letter. Such an order is to inform the alleged violator of his right to request a hearing within 30 days. If a hearing is not requested, the person is deemed to have consented to the order. If the person requests a hearing, the director is to hold a hearing according to the provisions in the law. The director may then reissue such orders as are warranted.

All orders, permits or other determinations of the director except those consented to are subject to judicial review. The Superior Court of the Commonwealth has jurisdiction in equity to enforce any such order, permit, determination, rule, or regulation issued under the law. The Superior Court, if the public health, safety, and interest require it, may enjoin any pollution prior to the final determination of any proceeding.

The Members of the Water Resources Commission individually and the Commissioner of the Department of Public Safety compose a board for the purpose of insuring that certain chemical and hazardous wastes are safely and properly handled and disposed of. The board is authorized to investigate the handling and disposal of such wastes and to coordinate the activity of agencies represented by the members of the board. The board can adopt rules and regulations to protect the public and its environment from the effects of unregulated handling and disposal of these wastes. The board delegates the responsibility for the administration of its rules and regulations to the most appropriate agency as represented by a member of the board.

After public hearing, the board can adopt rules and regulations:

(1) Identifying substances which constitute or may reasonably be expected to constitute a danger to the public health, safety, or welfare or to the environment and which should be handled and disposed of by licensed waste disposers.

(2) Specifying in what manner wastes may be handled or disposed of.

(3) Specifying the location in which such substances may be disposed of within or without the Commonwealth to prevent damage to any resource or to the environment.

(4) Establishing reasonable exceptions when scientific evidence satisfies the board that certain substances and quantities involved do not constitute a threat to the public and its environment.

(5) Establishing reasonable license and inspection fees.

(6) Establishing such other rules and regulations as necessary to assure that hazardous wastes are being properly handled and disposed of and to assure that such hazardous wastes are handled by licensees of the board.

Licenses are to be issued by the board to persons to handle and dispose of hazardous wastes. The terms and conditions of the license will be those set out by the board in accordance with its rules and regulations.

A violation of the laws with respect to the safety and proper handling and disposal of hazardous wastes and the licensing of persons to handle and dispose of such wastes are punishable by a fine of not more than $5000 and by imprisonment in jail or the house of correction by not more than six months, or both. The Superior Court has jurisdiction in equity to enforce the provisions of the law.

Any general or special law reference as to the authority to administer water pollution abatement or control laws in the Clean Waters

Act is intended to be referred to the Division of Water and Pollution Control. Laboratory services of the Department of Public Health are made available under the law to the Division of Water Pollution Control at cost.

3. Relevant Incidents

a. Methods of Investigating Complaints

There is little active effort by the Pesticide Board to control the sale, use and application of pesticides in the Commonwealth. Rather, it depends upon receiving complaints about those who are using or applying pesticides from citizens, government employees, and others. Unless such complaints are made, the board seldom investigates or makes other attempts to control pesticides under existing laws and regulations.

There have been numerous complaints and incidents regarding pesticides presented to and investigated by the Massachusetts Pesticide Board since the board was established. Complaints are made known to the board in a number of ways, but usually through phone calls, letters, or personal meetings with the executive officer of the board. The complaints handled by the board cover a broad range including accidental spilling of pesticides, fish kills, bird kills, and hazards such as airplanes flying over populated areas after or during pesticide spraying.

Complaints are all handled in a similar fashion. The executive officer of the board, as time and resources permit, attempts to investigate each complaint and to determine whether it is justified, the basis for that justification, and whether the Pesticide Board or another state agency should take any action with respect to the complaint. When complaints are considered by the personnel of the board, the investigation is thorough. In most cases all people who have had anything to do with the incident are interviewed and a summary of the interview information is retained.

Much time, knowledge, and skill is required of the investigator. He must be aware of technical pesticide used, their names, their proper application; he must be aware of alternative expalnations for the result which is being complained about; he must know which people and agencies to see about the problem; he must be aware of other aspects of the problem such as medical, social, legal, and environmental.

The investigator must interview people at length to find out what really happened or what was observed. He must be able to document the results through sampling and testing, through photography, and through witnesses. He visits the site of the incident and attempts to explore all possible explanations at the site with witnesses or complainants and with others who may be able to contribute alternative theories and support for them. The investigator spends a great deal of time in carrying out these elements of the investigation and must travel a great deal to do so.

The Massachusetts Pesticide Board has one employee charged with investigating incidents of pesticide misuse or harm caused to human beings or environment by pesticides. The same person is also responsible for administering all the rules and regulations of the board and for carrying out the law regarding pesticides when that responsibility falls to the board. This person must also handle all correspondence, much planning and policy, executive actions, record-keeping, and most of the social and political difficulties that arise from pesticide use and application. Consequently, because the Pesticide Board executive officer is so busy, the complainant often must request action by the board more than once if his complaint is to be followed up. The result is that too much of the burden of protecting against harm to human beings or the environment caused by pesticides is thrown upon citizens who might observe an incident which deserves the attention of the board. Moreover, the complainant must be skillful enough to locate the Pesticide Board within the state government to even deliver the complaint.

b. Synopses of Specific Incidents

(1) Mosquito fogging by golf course. The board received a request from the local board of health for assistance in dealing with citizen complaints about mosquito fogging operations carried on by a golf course. The executive officer of the board visited the operator of the course, accompanied by the director of the county mosquito control project in whose district the golf course was located.

The method of spray was a swing fogging device with a generator used to fog a mixture of 6% DDT, 2% chlordane, and 2% thanite in a petroleum distillate carrier. Spraying was done at about 8:00 p.m. on nights when mosquitoes were intense. The executive officer instructed the operator to use another more appropriate spray and to fog only when the fog would not cross the road to reach nearby homes.

The executive officer visited the complainant who showed him plants in their front yard that they claimed were damaged by the spray. Also, one complainant had been under treatment for a respiratory ailment which he indicated was aggravated by the spraying. They further complained that the kerosene smell got into their clothes and house and that the road was literally blocked because the fog was so thick.

The executive officer visited the Chief of Police in the town who reported the road was not blocked by fog at the time the cruiser arrived.

As a result of his investigations, the executive officer concluded that there was some justification for the complaints, but that the course did require a mosquito control program. He set out an improved program in detail which, in his judgment, would reduce the problem of drift and which took advantage of better mosquito control spray materials.

(2) Aerial spray to control mosquitoes in three towns. A series of complaints about dead and dying small birds was found throughout three towns which had just previously undertaken a helicopter spray program to control mosquitoes using Baytex at a rate of one ounce of 93% ULV per acre mixed with a petroleum solvent.

Fish and Game, Audubon Society, and Chemagro (the manufacturer of Baytex) personnel collected samples of the birds for laboratory analysis. The executive officer of the board received letters and phone calls indicating citizen outrage or concern, with estimates of the bird kill including "thousands" and "10% of the bird population." He determined that the Baytex was used properly and that it was loaded under the supervision of the superintendent of the area mosquito control district.

The results of some laboratory tests were presented to town meetings by the Audubon Society as not indicating that the spray program caused the bird kill. However, many citizens and public officials remained skeptical and scientific evidence was at best inconclusive. No results were ever made available from Chemagro's laboratory work.

(3) Aerial spray to control mosquitoes: A complaint was received by the board of slight fish kill in swampy areas and two specific ponds. A helicopter spray program was reportedly being carried out in the area using Baytex at a rate of 1/2 gallon per 60 gallons of water (about one fluid ounce per acre).

The board executive officer contacted the helicopter company who reported the use of Abate, not Baytex, at the same rate. Company personnel also indicated that the area being sprayed was heavily polluted from industrial, town dump, and other sources.

Investigation at the site did not result in observing any dead fish. Heavy pollution from other sources, however, was apparent. The executive officer concluded that any slight fish kill which existed was likely the result of this other pollution and reported this, with a summary of his field notes, in a letter to the complainant.

(4) Greenhead fly spraying program. A complaint was received by the board that the Cape Cod Mosquito Control District spray program for greenhead flies was causing plankton and clam kill in a nearby fisheries research facility.

Greenhead fly treatments of malathion in oil applied as a fog and ULV malathion were used in the general area on two occasions and plankton pools at the research facility stopped producing immediately after both treatments. When drained, cleaned, and refilled at high tide, the pools began producing again. Quahog clam kills in laboratory trays were also complained about.

The board executive officer visited the research facility, collected samples of water, mud, clams, and plankton and took them to the nearby Cranberry Experiment Station to be analyzed for chlorinated hydrocarbons. He also thoroughly checked out any pesticide use by the town and cranberry growers in the area and found that almost none had been used.

The laboratory results were inconclusive. The executive officer suggested a program of wider monitoring and additional testing, and the fisheries research facility agreed to contact appropriate laboratories who might be equipped to carry out such work.

(5) Mosquito larviciding program. The board received a complaint from a town conservation committee about a large fish kill in several local ponds. Several people had reported the incident to other local and state government agencies.

The executive officer of the board visited the sites and found many dead fish and some dead eels and arranged to have samples taken and analyzed. He discovered that a mosquito larviciding treatment had been made in the upland areas around the ponds in the morning using Baytex at one fluid ounce per acre in one quart of kerosene. In the afternoon, people swam in the pond, noting both fish kill and algae bloom. Two days later other persons noted fish kill. It rained that day, and diazinon was applied to cranberry bogs upstream from the ponds on that day. The next day another complainant noted fish kill and algae bloom.

The executive officer discovered a history of problems with these ponds, including past fish kills, silting, and so on. He concluded that the fish kill he was investigating could have been caused by oxygen deficiency, mosquito spraying, cranberry spraying, or a combination of all three.

(6) Aerial spray to control mosquitoes. The board received a complaint from a bee keeper that he had lost three hives due to aerial spraying to control mosquitoes in the swampland where the bees were located. The county bee keeper association also registered a complaint because of

the incident and asked to be notified prior to any spraying so that they could protect their hives.

The executive officer visited the complainant who had lost the bees and explained the existing rules and regulations regarding aerial spraying. Basically, these regulations require local law enforcement officers to be notified prior to spraying.

At a subsequent air sprayer meeting, the incident was discussed, the regulations of the Massachusetts Aeronautical Commission and the Federal Aviation Administration were discussed, and there was a concensus that all areas should be surveyed for beehives prior to spraying.

(7) Pesticide spillage at a public beach. The board received a complaint that a pesticide spray truck taking on water for spraying purposes at a public boat landing and beach area had discharged a large amount of milky liquid into the water. The complainant had called the local police.

The executive officer visited the local police chief about the incident and observed the site. No fish kill or other indications of the spill were evident, but other people had reported foam at the waters edge from the incident. He visited with the complainant who had observed the incident and reported it to the police. The complainant had observed a spill causing a milky liquid area in shallow water about 20 feet in diameter. The operator of the truck told the complainant that such discharges often occurred but that the mixture in the water was harmless because there was no pesticide in it. The owner of the truck indicated the mixture discharged was only spreader-sticker because the zineb-carbaryl pesticide had not yet been put into the tank.

The executive officer concluded that no apparent harm had resulted from the discharge, but he was very concerned about the site chosen to take on water and the careless manner in which the water loading was done. A letter was sent to the owner of the truck indicating that if any further violations of the rules or regulations occurred, appropriate action would be taken.

(8) Discharge of pesticide into a stream. A licensed applicator reported to the board that excess 2,4,D-urea 45 mixture had been dumped by mistake into a stream by a crew for which he was responsible. No attempt by the board was made to investigate the results of this dumping. However, a hearing was held to consider the incident by the board.

The applicator explained that the crew had violated his instructions, dumping the excess pesticide into the stream where they usually took on water instead of into a gravel pit as instructed. He argued that the incident was not a reflection on his competence, but a case of a subordinate not following instructions.

The board, in executive session, decided to send a letter to the applicator and did so, stating that disposal of pesticides was an important aspect of the proper use of pesticides and that further violations of the rules and regulations of the board could lead to the loss of the applicator's license.

(9) Application of pesticides without Massachusetts license. An applicator licensed in Connecticut applied to the board to be licensed in Massachusetts. His application was denied, but no reason for the denial was given. The applicator asked for a hearing before the board, the request was granted and the hearing date set, but was postponed because the applicator's attorney could not be available.

A complaint was then received by the board from a Massachusetts citizen that the spraying of a crop by this same applicator in Massachusetts had damaged cucumbers not located in the spray target area.

The next day the executive officer of the board investigated the applicator in Connecticut and found him to be licensed there. On that same day the complainant made another complaint to the board regarding a second spraying by the same applicator. This time, the complainant called the state police. The applicator told the police he was working under the license of a Massachusetts firm which had licensed personnel.

Three days later, an officer of the applicator's firm in Connecticut called the executive officer and stated that the applicator had made an honest mistake because the Massachusetts firm had told him that he was working under their license. However, the Massachusetts firm denied they had ever implied that the applicator could work under their license. On the same day, the applicator sprayed again in Massachusetts and the complainant called a local constable to have the spraying stopped.

Two days later, the board was informed that the same applicator had been hired to spray the Suffolk Downs Racetrack property. The executive officer indicated that he was not licensed and thus could not carry out the program. As a result, the management of Suffolk Downs obtained another contractor to do the spraying.

After discussion with the Chairman of the Board, the case was referred to legal counsel for the Department of Public Health for presecution. Subsequently, the applicator again made formal application for a Massachusetts license. Apparently, no action has ever been taken on either matter.

(10) Aerial spraying of potatoes and disposal of pesticide containers. Several citizens complained to the board by letter and phone about drifting spray materials and the nuisance of a low-flying airplane being used to spray potato fields near their homes.

The executive officer visited the site and noted herbicidal effects at the field edges and well onto property of adjacent landowners. He found the pesticide storage area used by the potato grower unlocked. Many pesticide containers were on the ground, including three parathion bottles with significant amounts of concentrated parathion remaining in each one. Water in a nearby ditch leading to other streams and ponds was a deep yellow color, having been contaminated with dinitrophenol, a potato-top killer.

The executive officer write a strong letter to the potato grower regarding these findings and requested a meeting to discuss them personally.

(11) Fire in a pesticide storage area. A barn at a country club in which pesticides were stored burned, and water hosed over the burning building ran into a nearby private pond killing all or nearly all the fish in the pond. A series of wells serving as a public water supply was located about 3/4ths of a mile downstream from the pond.

The executive officer helped arrange for a laboratory analysis of the water which showed that the pesticides in the barn were amanate, thiram, actidione, and one other that could not be named by the laboratory.

(12) Truck accident causing pesticide spillage. The board received a report of a pesticide spill as a result of a truck accident. The executive officer contacted the witness and found the accident had occurred at 8:30 p.m., causing one drum to break open. He then contacted the trucking company. The company said the accident involved one drum of

parathion, 98%, for manufacturing use. The drum fell from the truck onto its top and came to rest leaking. Only one pound of material was lost as determined by weighing the drum. The spill on the pavement was wet down with a bleach solution, adsorbed into chlorinated lime, and swept up. The spill on the highway median was covered with chlorinated lime. The truck was not contaminated.

The executive officer visited the site of the accident and found no odor nor any remaining evidence of parathion. The area was still liberally sprinkled with lime at the time of his visit.

(13) Cranberry spray program. Fish kill in two ponds was reported by town officials to the Division of Fish and Game. Investigation by the division indicated that DDT and Guthion had been used in cranberry bogs on tributaries of the ponds and that accelerated runoff had resulted from substantial rainfall at the time of the fish kill.

The next day and on subsequent days, water and fish samples were taken for analysis. About 500-600 pounds of dead fish were observed (bluegills, brown bullheads, yellow perch, white perch), and fish were observed in shallow areas exhibiting nervous spasms. They could easily be caught by hand. The duration of the kill was about two days.

Laboratory analysis showed negative results at 1 ppb sensitivity for chlorinated hydrocarbons including DDT in water samples. However, Guthion, an organophosphate showed concentrations of as high as 12.57 ppb in water samples. The 96-hour TL_M of Guthion for bluegill is 5.2 ppb, and two of four samples from one pond and two of three samples from the other showed concentrations higher than these. Consequently, the Division of Fisheries and Game concluded that Guthion caused the fish kills in both ponds.

C. OTHER NEW ENGLAND STATE'S REGULATION OF PESTICIDES

1. ORGANIZATIONS

a. Connecticut

Connecticut has a State Board of Pesticide Control with the following members:

Voting

Commissioner of Agriculture and Natural Resources

Commissioner of Health

Director of the Connecticut Agricultural Experiment Station

Non-voting

Chairman of the State Board of Fisheries and Game

Chairman of the State Park and Forest Commissions

Chairman of the Water Resources Commission

Chairman of the Shellfish Commission

Highway Commissioner

Three members appointed by the governor

One of the members is appointed by the governor as chairman of the board.

b. Maine

Maine has established a Board of Pesticides Control with the following members:

Commissioner of Agriculture

Commissioner of Health and Welfare

Commissioner of Forests

Commissioner of Inland Fisheries and Game

Commissioner of Seas and Shore Fisheries

Chairman of the Public Utility Commission

Highways Commissioner

Water Improvement Commissioner

The board elects a chairman from its own membership each year. Commissioners of the state departments may appoint agents to serve in their absence.

c. New Hampshire

New Hampshire has established a Pesticide Control Board with the following members:

Commissioner of Agriculture

Director of the Division of Public Health Services

Director of the Division of Resources Development

Director of the Fish and Game Department

State Entomologist

Executive Director of the Water Pollution Commission

Four (4) members appointed by the Governor.

The Governor makes his appointments as follows: one member from the general public, one member from the slate of three persons presented by the New Hampshire Horticultural Society, one member from a slate of three persons presented by the Hew Hampshire Arborists Association, and one member who is a recognized ecologist, preferably holding a doctorate in ecology.

The board selects its own chairman. However, the Executive Director of the Water Pollution Commission is the Executive Secretary of the board and coordinates the information and data developed by the Water Pollution Commission and the Department of Agriculture under the statute.

d. Rhode Island

Rhode Island established a Technical Pesticide Advisory Board with seven members:

The Director of Natural Resources (ex-officio and chairman)

The Director of Health (ex-officio)

Two members representing the public and appointed by the Governor

Two members representing the disciplines of ecology and acquatic biology appointed by the Chairman of the Board of Regents

One member from the Agricultural Experiment Station appointed by the administrative head of the station

The board is responsible for advising the Director of Natural Resources concerning policies, plans and goals to be attained in administering pesticides control legislation, and to make recommendations to the Director at least annually. The board is also to review, comment and present recommendations on all regulations proposed by the Department of Natural Resources before public hearings are held on such regulations or before they go into effect, whichever is earlier.

e. Vermont

Vermont has established a Pesticides Advisory Council, the membership of which is constituted by representatives with knowledge of pesticides from the following:

Fish and Game Department

Department of Water Resources

Department of Agriculture

Department of Forests and Parks

Department of Health

Aeronautics Board

Physician from College of Medicine, University of Vermont

Person engaged in Pesticide Research from Vermont Agricultural Experiment Station

Person engaged in entomology from Vermont Agricultural Experiment Station

The Chairman of the Council is designated by the Governor, serves as his personal representative, and coordinates the activities of the council.

2. LAWS, REGULATIONS, AND REGULATORY PROCESSES

As indicated in the section above, all northeast states (Connecticut, Maine, New Hampshire, Rhode Island, Vermont) including Massachusetts have some type of pesticide control board. The purpose of the pesticide control boards is similar in all states. Basically, it is to safeguard the public health, welfare, and environment from harmful effects caused by hazardous pesticides.

The substance of the legislation establishing these pesticide control boards is also similar. Included are the registration of licensing of commercial applicators and of other personnel who deal with pesticides. In most states the board can require an examination before a person is licensed as a pesticide applicator. Such licenses may have restrictions or may be limited to certain uses. The licenses may be suspended by the boards either before or after hearing and the boards are all authorized to revoke or modify the licenses if the licensee has violated the rules, regulations, or laws governing pesticides or for other reasons. Reciprocity is given by all states to other states who have similar licensing procedures and who also grant reciprocity. Exemptions from the licensing procedure usually include experimental uses of pesticides by universities and other scientific personnel and property owners when applying pesticides in or immediate around buildings which they own. Exemptions are sometimes given for bona fide farmers and arborists. Arborists in most states, however, are licensed to care for trees, shrubs, and other similar plants under a separate statute, often with separate rules and regulations. In most states the arborist is required to have a license from the Pesticide Control Board before he can apply pesticides in the course of his work.

Many states require a proof of financial responsibility from commercial applicators in the form of a certain amount of liability insurance.

In all states members or personnel of the board may inspect equipment and techniques used to apply pesticides and are permitted to go onto property at reasonable times to do so. In some states they may require repairs before equipment can be used for pesticide applications.

In nearly all states the board requires records to be kept by commercial and other applicators and to be made available to the board upon request. In some states, such as New Hampshire, such records are mandatory under the law and not discretionary with the board. In fact, the New Hampshire law requires the board to keep the list of licensed applicators, permit holders, and of the quantities of pesticides used in the state.

All states require that one licensed member must be with each applicator crew during spraying.

All pesticides boards are authorized to adopt regulations, and rules as necessary in order to control the sale, use and application of pesticides.

The enforcement of the law and the rules and regulations of the pesticides boards varies from state to state. In New Hampshire the board is authorized to enforce its rules and regulations and the law which created and gave the board its powers. In other states, such as Maine, the personnel of the state agencies represented on the pesticide control board are authorized to enforce the laws, rules and regulations of the board as seen to be most appropriate by the members of the board.

Most boards can suspend the regulations in order to better or more effectively combat an emergency.

The law in some states provides a mechanism for persons aggrieved by any board action to appeal the action. In Maine, a person may appeal a board action directly to the courts.

The penalties for violation of the laws, rules, and regulations governing pesticide sale, transportation, use, and application of pesticides vary from $100 per violation for the first violation, to $500 for such first violation but do not go higher that $500 for each violation except in the case of aerial applications of pesticides for which, in some states, the fine is as high as $1,000 per violation.

The responsibilities of the pesticide boards vary from state to state. In the case of Vermont, there is a pesticide advisory council whose responsibilities include advising the executive branch on legislation and suggesting programs, policies, and legislations to the executive branch. In addition, the council prepares a summary of hazardous pesticides needing control. It also reviews control programs using pesticides for safety and efficiency and serves as an advisory board to the aeronautics board on aerial applications of pesticides. These duties are more general and more policy oriented than are the duties of most other boards. Usually, the boards regulate the sale, transportation, use, and application of pesticides through means of registration, labeling, and licensing, by promulgating rules and regulations, and by making provisions for enforcing these regulations. In Maine, for example, the board regulates all applications of pesticides and charged by law with designating critical pesticide use situations, limitations on the use of pesticides, and spelling out what constitutes unsafe practices in using and applying pesticides.

In the Vermont statute the Commissioner of Agriculture is charged with the responsibility of regulating the sale and use of pesticides. He only acts upon the advice of the pesticide advisory council and with the approval of the Governor. The powers spelled out in the act are the powers of the Commissioner and not of the board. However, powers are very similar to those given to pesticide boards in other states.

The regulations promulgated by the pesticide boards in the northeastern states are similar in many respects. Applicators under most regulations are charged with cooperating with the board and its personnel who are investigating, sampling, and otherwise observing pesticide application techniques used by applicators.

Safety is handled under most board regulations by a statement indicating that the licensee will instruct himself and all personnel as to the dangers and problems of pesticide use and will supply the safety equipment required to safeguard personnel against hazards from the use of application of pesticides.

Reports of pesticide use are only required in states of Maine and New Hampshire. In other states such reports can be requested by the board but they are not required as a part of the normal course of events in utilizing or applying pesticides.

Most regulations indicate that the use of any pesticide not registered by the state and sometimes also by the Environmental Protection Agency or the U.S. Department of Agriculture are prohibited in the state.

A significant number of circumstances is set out in board regulations in the northeast states requiring the approval of the boards before specific pesticides can be used in certain ways or applied in certain areas within the states.

In Maine, for example, there is no pesticide application allowed on or in any water or water supplies within the state without approval of the board. Application for such approval must be made in writing with ample detail for the board to justify a decision to allow such pesticide applications to proceed. There can be no machine applications, overflow, spilling, or washing from any machine used to apply pesticides into any water supply in the state without approval by the board.

The disposal of empty containers and surplus pesticides is not covered by rules and regulations in all northeast states. In Maine a recent revision of the pesticide control regulations indicates that empty containers should be returned to the manufacturer or to a reconditioning company and that empty containers which cannot be returned or reconditioned should be stored in a safe place or buried or returned to the manufacturer.

In Vermont, pesticide drift is to be minimized, and pesticide operators should buy marerials and conduct operations under conditions known to minimize the contamination of other than target land and target organisms. A statement on standard operating procedures is also included, indicating in a general way that all persons engaged in the business of pesticide uses should use only methods and equipment which insure proper application of the materials, should operate in a careful manner, and only when pest and crop conditions are proper for controlling pests in the locality.

Only in Vermont is the protection of bees and other pollinators specifically provided for in the regulations.

In New Hampshire, board regulations state that no pesticide can be applied on water, public watershed areas, or on marsh land for mosquito control without board approval. No surface water application for any reason is allowed without board approval in New Hampshire, nor is any application by plane.

D. DEGREE OF ENVIRONMENTAL PROTECTION PROVIDED BY EXISTING LAWS, REGULATIONS, AND PROCEDURES

1. Introduction

The existing laws and regulations governing the sale and use of pesticides in the study area are generally adequate. They provide broad powers for establishing regulations and authority to monitor and otherwise control activities dealing with pesticides. However, the powers created by law are not excercised because of lack of money, facilities, and personnel. The result is that the requirements of the law are not well known by those who use pesticides, there is virtually no knowledge of how well the sale and use of pesticides conforms to the laws and regulations, there is little done to monitor or control pesticide activities under the laws and regulations, and little effort is devoted to monitoring developments in the pesticides field and to the integration of these developments into state programs and practices. Consequently, the degree of environmental protection that could be provided by existing laws and regulations is not attained because an insufficient level of effort is devloted to assuring that procedures and practices conform to these laws and regulations. The Massachusetts Pesticide Reclamation Boards each have one executive person to carry out monitoring, investigation, and other control activities, correspondence, and other actions under the laws governing pesticides. The executive officer working for the Pesticide Board is the official source of pesticide control information in the state and must maintain all records, files, and carry out nearly all other administrative duties of the Pesticide Board. He has no lavoratory facilities, technicians, or other skilled personnel to assist him. The person working for the Reclamation Board is in a similar situation. In addition, he faces directors in the mosquito control districts who are used to operating without supervision or control. As a result, the public interest in the sale, transportation, use, application, or effects of pesticides is not adequately protected.

There are two basic approaches that could be used to solve this problem. First, the law governing pesticides could be made very specific so as to require certain activities on the part of the executive agencies of state and local government. Second, the present broad and flexible legal authority could be utilized better by more adequately financing and staffing the executive arms charges with responsibility for pesticide and vector control.

The second option would be preferable because it can meet public and individual needs more precisely and speedily. It is not clear what exact confluence of events is necessary to attain it. However, it will likely require a clear presentation of the needs for additional funds, the request of such funds as a part of the executive budget request, a sympathetic legislature, and perhaps a higher degree of public awareness and reaction to the pesticides control issue so as to alter its priority among other public interests requiring funds.

2. Regulation of Sales

The sale of pesticides at the wholesale and retail levels in Massachusetts is virtually unregulated. Massachusetts legislation provides that no wholesaler or distributor other than a person selling at retail can sell, offer to sell, distribute, or deliver a pesticide within the Commonwealth unless he has a license to do so from the Department of Public Health.

In addition, the licensee shall, at the request of the pesticide board but not more often than once a year, supply the board with information concerning the quantities of pesticide sold which are being regulated by the board or which are being considered for regulation by the board, including the names and addresses of purchasers or recipients. The Department is charged under the law with issuing a license once it has determined that rules and regulations promulgated under its authority to regulate sales have been met. However, these regulations have not yet been drafted, and no licenses are being issued.

Thus, in practice no attempt is made in the Commonwealth to control sales, to monitor them, or to determine the nature of the problems at the wholesale and retail sales levels. Little information is made available to retailers about the kind of sales that can be made and about details of handling special permit sales, experimental use sales, and other similar sales. No records are required of the retail sale of pesticides under the law.

Certain acts are, however, unlawful. These include to distribute, sell, or offer for sale in the Commonwealth or to deliver for transportation or transport in interstate commerce or between points within the Commonwealth throughout any point outside the Commonwealth any of the following:

1. Pesticides not registered or not the same when sold as when registered.

2. Pesticides, unless they are in the registrant's or manufacturer's immediate container and properly labeled.

3. Pesticides highly toxic to man and not properly labeled.

4. Pesticides not discolored which are required to be discolored.

5. Pesticides which are adulterated or disbranded, or any device which is misbranded.

However, only a few of these acts come to the attention of the Department or the Board unless reported by a citizen or member of another governmental agency.

3. Regulations of Uses and Application Techniques

By regulation, the Massachusetts Pesticide Board has prohibited the use of DDD (TDE), aldrine, endrine, heptachlor, and marine anti-fouling paints which contains mercury in any form or compound.

In addition the board has restricted the use and applications of dieldrin, chlordane, BHC, 2, 4, 5-T and its esters and salts, DDT, and toxaphene. Activities dealing with marine anti-fouling paint containing mercury which is already applied are restricted also.

The regulations of the board state that no person shall apply or use a limited or prohibited pesticide except in accordance with the permit issued by the board and subject to such restrictions as are imposed by the board in the permit. All such permits are revocable and may be revoked without a hearing by the board at any time.

The permit or proof that such a permit is held by a person must be exhibited or furnished when purchasing such prohibited or restricted pesticides. No one can sell or distribute any pesticide listed as a prohibited or restricted pesticide except to a person holding such a permit and then only in accordance with the conditions which are contained in the permit.

Despite these regulations, the board is not effectively regulating the sale, use, or application of these pesticides. The board makes few efforts to provide information about and to enforce these regulations. As a result, the degree of voluntary compliance with the regulations is not clear and the deliverate violator is pretty much free to proceed as he desires.

4. Regulation of Containers

Regulations governing the disposal of pesticide containers are the responsibility of the Department of Public Health, and no regulations have been promulgated. Re-use of containers is subject to the regulations of the Pesticide Board. No planned efforts are made by the board to control the disposal of pesticide containers. In fact, even when a significant incident involving container disposal has arisen (see the section above on pesticide incidents), the board has not taken action to enforce the penalties available under existing laws. As a result, the environmental protection afforded by existing laws, regulations, and practices cannot be considered to be adequate.

5. Regulation of Surplus Pesticides

The disposal procedures of surplus pesticides is set out in detail in the regulations of the Pesticide Board. However, no attempts have been made by the board to monitor such disposal and to enforce the regulations. An example is the pesticide incident cited above in which a surplus pesticide was dumped into a stream. In dealing with this serious violation, the board, judging from the available record, did not consider the fact that the applicator's original instructions to the crew to dump the surplus pesticide in a nearby gravel pit also violated the regulations.

6. Regulation of Pesticide Accidents and Treatements

The board has not promulgated specific regulations dealing with pesticide accidents and their treatment. However, Massachusetts does participate in the Pesticide Safety Team Network sponsored by 12 members of the National Agricultural Chemical Association, and it is the board's policy that the procedures necessary to utilize the emergency system be used in the case of pesticide accidents. Participation in the program is voluntary, however, and the board has no authority to make parties follow its established procedures. As a result, adequate environmental protection is not assured in the area of pesticide accidents and treatments.

7. Factors Influencing the Use of Available Regulations

a. Financial

Lack of adequate funds, personnel, and facilities is the most important factor influencing the degree of environmental protection presently attained under existing laws and regulations.

b. Institutional

Lack of coordination between governmental units involved with or affected by pesticides is another factor diminishing the degree of environmental control that could be attained under existing pesticide laws and regulations A lack of awareness of their potential for identifying pesticide related problems and solutions appears to be a common characteristics of local government agencies and of state government agencies whose primary objective is not to effectively utilize or to control the sale, transportation, use, or application of pesticides.

c. Social

An increasing public awareness about the use and effects of pesticides has prompted increased inquiries and complaints by citizens about all aspects of pesticide sales, transportation, use, and application. Although often based on fear and incomplete understanding, these inquiries and complaints are a prominent factor in influencing state and local governments to more fully use available control mechanisms to deal with pesticides problems. Various citizen conservation groups have been especially effective in monitoring the activities of state agencies, private firms, and individuals who sell, transport, use, or apply pesticides, and they are often well informed about the rules and regulations and technical aspects of pesticides.

However, the major socio-economic element influencing the use of available controls for pesticides in the Commonwealth is the relatively low priority given to the pesticides control issue by the general public. The concern of the general public about pesticides and critical incidents with respect to pesticide sales, use, transportation, and application is low. As a result, political decisions about funding pesticide control efforts turn on the more highly charged matter of taxes and the level of overall governmental expenditures. The generally low visibility of the pesticide control issue allows the executive and legislative branches, in attempting to balance funding requirements with all ogvernmental priorities, to give the control of pesticide sales, transportation, use, and application a fairly low level of priority. The lack of crisis type pesticide incidents has allowed this situation to continue.

d. Legal

There is not sufficient legal talent and energy at the state and local governmental levels to effectively utilize existing control mechanisms. New regulations, administrative hearings, court cases, brief writing, and enforcement actions often require legal inputs. With these inputs in short supply, decisions of the executive officers of regulatory boards such as the Pesticide and Reclamation Boards may be faulty or may not be made at all.

E. STRENGTHENING THE ENVIRONMENTAL PROTECTION AFFORDED BY EXISTING LAWS, REGULATIONS, AND PRACTICES

1. Regulation of Sales

The most effective mechanism for regulating the sales of pesticides would be to provide complete information about the rules and regulations to all who sell or distribute pesticides, to make a significant number of observations and spot inspection visits, to back this control procedure up with adequate technical facilities, and to objectively and strictly enforce the laws and regulations. This is not occuring at the present time in the Commonwealth because of lack of finances and personnel.

Moreover, recent legislation has established a licensing system for pesticide wholesalers and distributors in Massachusetts. Licenses are to be granted to those who meet requirements under rules and regulations to be promulgated by the Department of Public Health. At the time of its passage, pesticide retailers were exempted from licensing because the administrative burden of licensing so many retail outlets was thought to be too great. Since this passage in 1970 no rules and regulations governing the licensing have been promulagated by the department. It is the feeling of some in the department that the licensing procedure would be a complex and energy absorbing, but sterile, process because there have never been sufficient personnel in the department to monitor any of the standards set out for pesticides registration, labeling, sale, transportation, use, and application. As a result, the approach for regulating sales has shifted somewhat in the department from an emphasis on licensing to an emphasis on monitoring sales activities. To that end, the department has had legislation filed for consideration in the next legislative session that would authorize them to use local boards of public health for monitoring pesticide sales in certain circumstances.

2. Regulation of Uses and Application Techniques

The Pesticide Control Board is attempting to promulgate regulations that, if followed, will properly control the use and application of pesticides. However, it requires a core of personnel to disseminate information, to monitor and spot check pesticide use, and to instigate pesticide enforcement proceedings. The Board also needs personnel who can take samples and carry out other technical tasks. It requires ready access to laboratory personnel and facilities for testing samples and for the technical analysis of pesticide related problems. Without these, the pesticides control law and regulations dealing with uses and application techniques are empty except in so far as investigation of reported incidents and voluntary compliance combine to make the laws and regulations effective.

3. Regulations of Containers

The disposal of used pesticide containers is virtually uncontrolled in the Commonwealth because there are no laws or regulations that govern it. The Department of Public Health is authorized to promulgate regulations in this area. Such regulations should be written because of their value in educating persons using pesticides as to the appropriate methods of disposal. Also, a significant amount of voluntary compliance with such regulations is likely.

Additional resources, as in the case of pesticides use and applications, are required, however, before the degree and precision of control desired in this area will be forthcoming. Especially important would be the designation of state approved sites and methods for disposing of used pesticide containers, to include sites for treating such containers to render them harmless before disposal.

The regulation of containers filled with pesticide material is limited under existing law. Additional standards as to the type and specifications of pesticide containers would help assure safe transport, handling and marketing.

4. Regulation of Surplus Pesticides

The regulations governing the storage or disposal of surplus pesticides appear adequate. The gap between the regulations on paper and actual practices, however, it unknown. Additional efforts must be made to monitor this area under the existing regulations to assure that the storage and disposal procedures that are actually being used will not endanger people or the environment. Again, these efforts hinge upon sufficient personnel, finances, and facilities for strengthening information inflows and outflows in this area and for instigating any necessary investigation and enforcement procedures.

5. Regulation of Pesticide Accident and Treatments

More emphasis by the state government, especially the Pesticide Board, on individuals or firms that manufacture, transport, distribute, sell, use, and apply pesticides as to the importance of appropriate pesticide accident reporting and treatment procedures is necessary. Fire Departments must be trained in how to respond when dealing with pesticide fires. Common carriers should know how to report and treat pesticide accident cases. Individuals dealing with pesticides in any way should be more cognizant of the dangers involved in a pesticide accident and of the way in which such accidents should be handled. Regulations to the effect that mandatory reporting of such accidents to the Pesticide Board be required, might be appropriate for accidents involving common carriers. Other types of accidents, such as those which cause waterways, food supplies, or similar items to be contaminated could be included as accidents for which mandatory reporting would be required.

6. Control Mechanisms

Control mechanisms written into the laws or regulations governing pesticides include the following:

1. Labeling
2. Registration
3. Inspection of records, equipment, and pesticide use and application activities
4. Licensing
5. Detention, embargo, and condemnation
6. Equity proceedings
7. Fines and prison sentences
8. Bonding
9. Public notice and hearings
10. Appeals procedures
11. Civil or equity proceedings

Items one through eight are mechanisms operated by state or local government in an attempt to attain the objective of protecting the public and environment from harm caused by pesticides. Items nine and ten are mechanisms operated by the government, but with the intent of providing all who have standing with an opportunity to be heard and to challenge decisions made by the various levels of government dealing with pesticides. Item 11 is a mechanism for dealing with disputes between parties, often between two individuals or private firms, but sometimes between a public servant or institution and a private individual or firm. In 1971, an act was passed an signed in Massachusetts authorizing 10 or more persons to petition the Superior Court it they have reason to believe that a person has damaged or is about to damage the environment. This new liberalized policy granting any interested parties standing to bring a cause of action on environmental matters should increase the public visibility of pesticide incidents and force a clearer resolution of some of the specific issues that have been handled only by the executive personnel of the Pesticides Control and Reclamation Boards and by other state and local government agencies. These resolutions arrived at in the glare of the public limelight, should have a credibility in the eyes of the media and the public that has never been given to the less visible decisions of the Pesticide Board. It is likely that this mechanism will become an important means of controlling pesticide uses and application if more active state and local monitoring and enforcement does not occur.

In the Commonwealth, these available control mechanisms are not well used. Some, such as a labeling, registration, and licensing are formally exercised, but their accomplishment tends to give an aura of "everything is all right now," when, in fact, the process of receiving and logging labels, registrations, and licenses creates a mere shell. The nature of the labels and content of pesticides that are actually being sold in the Commonwealth and the actual practices used by licensees in applying pesticides is not monitored. As a result, there is little knowledge about what is really happening with respect to pesticide sales, transportation, use, and application.

Although it is likely that there is a substantial amount of voluntary compliance with the laws and regulations, there are circumstances where it is in the individuals' or firms' best economic interest to violate the laws and regulations governing pesticides activities. Where there is little likelihood of ever being apprehended by state authorities, these situation are likely to result in violations. Thus, the lack of knowledge and effective control of pesticides in Massachusetts leaves the door wide open for one or more critical pesticide incidents that might have otherwise been avoided and for significant, but untraceable to a certain pesticide use or incident, effects in both the short and long run on people and their environment.

State and local governments need to expand their use of control mechanisms and to combine it with a larger program for providing information to those who use pesticides and those who are affected in some way by pesticides. This would probably cause more use of other control mechanisms such as detention, embargo, and condemnation proceedings, equity proceedings, and fines. To date in Massachusetts these control mechanisms have not been used for purposes authorized by the act regulating pesticides.

7. Coordination

There should be a significant increase in coordination between all state and all local government agencies and individuals concerned with the effect of pesticides on the public and the environment. For example, an inter-departmental group including all the personnel who actually carry out the execution and technical aspects of pesticide control policy, could be designated at the state level. The group could meet when necessary to coordinate activities and to adjust practices and procedures so as to more effectively attain the state's objectives in controlling pesticides. This group should develop and implement plans to coordinate their activities and programs with counties, cities, towns, and local agencies, such plans to be approved by the Pesticide and Reclamation Boards.

The activities of state governmental agencies and local governments or governmental agencies should be better coordinated. The state Reclamation Board, for example, does not have control of or complete knowledge of the program of mosquito control districts in practice, although it is supposed to have such control and knowledge under the law. Board appointed commissioners select the director of the mosquito control districts without guidelines as to their qualifications. Moreover, the directors do not feel directly responsible to the board. Several directors have held their positions for some time, and find it difficult now to openly submit their procedures for review by personne of the board.

Cities and towns have also conducted mosquito control efforts on an individual basis for a long time without submitting their programs to the board for approval as required by law. Early in December 1971, the board sent a letter to each city and town in Massachusetts explaining the existing laws and pointing out the obligation to obtain board approval of any mosquito abatement efforts before they are undertaken. Strong follow-up efforts are necessary to assure that all mosquito control programs are consistent with pesticide control policies. Such efforts, however, are unlikely because the board has only one person to deal with all the programs and problems of existing mosquito control districts and the activities of the individual towns.

IX. ALTERNATIVE (NONPESTICIDE) METHODS OF MOSQUITO CONTROL

A. LIFE HISTORY OF MOSQUITOES AND ITS EFFECT ON CONTROL

All species of mosquitoes undergo complete metamorphosis with four stages of development: egg, larva, pupa and adult (imago). The large number of species and their diversity, however, allow for great differences in the conditions necessary for development.

1. Development Stages of the Mosquito[1,2,3]

- Egg

The adult female mosquito selects the habitat required for the aquatic stages of the mosquito. Some species place the eggs in permanent bodies of fresh water, others utilize salt water, and still others lay eggs in small temporary pools or in dry grass which will eventually be subject to flooding. Eggs which are laid in moist areas but which do not have sufficient water may remain dormant for months and may not hatch until the following year.

- Larva

Under the proper conditions of moisture and temperature, the eggs hatch and the larva cuts its way out of the egg. The larva molts (sheds its skin) four times during its growth period and the stages between molts are called instars. Except for larvae of the genus Mansonia, all mosquito larvae must come to the water surface to obtain oxygen. Mansonia larvae and pupae attach themselves to the submerged roots and stems of plants and obtain oxygen from the plant tissue. Most larvae eat small plants and animals by sweeping them into the mouth with mouth brushes or by nibbling on the material. A few larvae are predacious and feed on other species of mosquito larvae. The time spent in the larval stage may be as short as 4 to 6 days or as long as several months, but typically is approximately a week to 10 days.

- Pupa

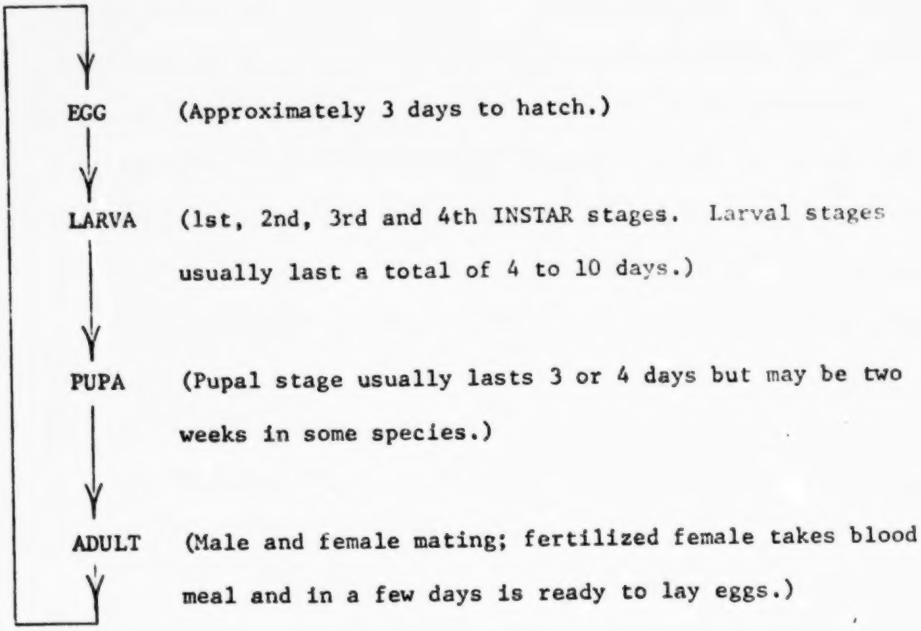
After the fourth molt, the pupal stage appears. The pupa normally rests at the water surface. When frightened, the pupa can dive with a tumbling motion but it must return to the surface for air. Typically the pupal stage lasts for 3 or 4 days but in some species may be 2 weeks or more.

- Adult

The adult breaks the pupal skin and emerges slowly, using the cast-off skin as a float until its body dries and hardens. Female mosquitoes are able to suck blood from an appropriate host organism. Male mosquitoes are not equipped to suck blood. Many species of mosquitoes attack man but others attack wild and domestic animals, and some attack nonmammalian species, such as birds, amphibia and reptiles. Depending on the species of mosquito, mating between males and females may take place at rest on some object, such as a shrub or grass, or while flying. Females of several species may pass the winter in hibernation in a protected place whereas others overwinter in the egg stage or even in the larval stage.

2. Effect of Life Cycle on Mosquito Control

The life cycle of the mosquito is illustrated in Figure IX-1. Depending on the species of mosquito and the temperature, the total time for a complete life cycle may typically vary from 16 days to 45 days if environmental conditions are reasonably satisfactory for all stages of the life cycle. On the other hand, lack of suitable conditions may lengthen the life cycle dramatically. For example, Aedes species may lay eggs in places which are above the existing water line and which may not be flooded until the following year. Thus, instead of hatching in a few days, the fertilized egg will remain dormant for several months until it is covered with water. Water temperature has an effect on the time required for hatching of eggs and development of the larvae.



EGG (Approximately 3 days to hatch.)

LARVA (1st, 2nd, 3rd and 4th INSTAR stages. Larval stages usually last a total of 4 to 10 days.)

PUPA (Pupal stage usually lasts 3 or 4 days but may be two weeks in some species.)

ADULT (Male and female mating; fertilized female takes blood meal and in a few days is ready to lay eggs.)

FIGURE IX-1. LIFE CYCLE OF THE MOSQUITO. (Typical life cycle requires 16 to 30 days but cold weather may extend it to 45 days or even over winter in some species.)

Low temperatures inhibit the development of larvae, sometimes to such an extent that some species overwinter in this stage. Extremes of temperature both high and low can kill the mosquito in the egg, larval or adult stage.

While mosquitoes are subject to attack by predators, parasites and diseases both in the aquatic stages and as adults, control by natural enemies or by artificial means is extremely difficult. In an area such as Cape Cod there may be 25 or more species of mosquitoes all with different life cycles, breeding places, and seasonal preference. In addition, the rate of hatching and growth of various species may be dependent on uncontrollable conditions, such as temperature and rainfall.

B. NATURAL ENEMIES OF THE AQUATIC STAGES OF THE MOSQUITO

- Plants

Certain aquatic carnivorous plants will trap mosquitoes and other plants may inhibit mosquitoes by covering the surface of the water and blocking access to air or by producing toxic by-products. Sometimes the inhibition may simply be due to an excess liberation of oxygen which can change the microflora of the water and may also bring in predacious fish.

Two algal species (Chara elegans and Cladophora glomerata) have recently been described[4] which produce inhibitory substances that prevent the growth of mosquito larvae, possibly by attacking the lining of the larva's alimentary canal. While Dr. Reeves indicated[5] that the algae apparently control mosquitoes in streams in which they grew, much additional research is required to elucidate the structures of the inhibitory substances, their mode of action and the feasibility of making and using the substances in practical mosquito control.

Garlic extracts have been shown to be larvicidal[6] and two substances, diallyl disulfide and diallyl trisulfide, have been isolated and identified as the larvicidal principles[7].

- Lower Forms of Animal Life

Hydra may destroy larvae and *Vorticella* may cause the death of larvae by excessive growth on their bodies [2] Water snails may feed on mosquito eggs and water fleas (*Daphne*) may destroy larvae.[2]

- Arthropod Predators

Arthropod[5] predators such as *Limnesia* have been reported to attack young mosquito larvae. In the order of *Coleoptera* (beetles) larvae of *Hydrophilidae* and *Gyrinidae*, as well as both adults and larvae of *Dytiscidae*,[9,10,11] are natural predators. Dragonflies[12] (*Odonata*) are well-known predators on adult mosquitoes but their larvae also attack certain mosquito larvae. Various bugs[13,14] (*Hemiptera*) are also active in destroying mosquito larvae.

- Cannibal Mosquito Larvae

The larvae of a number of mosquito species,[2] such as *Psorophora*, *Lestiocampa*, *Corethra*, *Eucorethra*, *Mochlonyx*, and *Chaoborus*, have cannibalistic habits and eat larvae of other mosquito species.

- Fish

Among the most effective of all natural enemies of mosquitoes are small larvivorous fish. The tropical or semitropical mosquito fish (*Gambusia*) has received the most attention. However, other fresh water and brackish water fish are also instrumental in the natural control of mosquito populations. Because fish have been used fairly successfully in the control of mosquito populations in certain areas, the subject will be discussed at greater length in a following section.

- Other Vertebrates

Frogs and toads and their tadpoles are not usually larvivorous but some species have been known to destroy mosquito larvae.[2] Ducks and other aquatic birds also destroy larvae.[2]

C. NATURAL ENEMIES OF THE ADULT MOSQUITO

Spiders capture the adult mosquito by catching them in their webs.[8] Dragonflies[12] and certain wasps are able to capture flying mosquitoes on the wing.[2] Among the vertebrates, frogs and lizards have been observed to feed on adult mosquitoes.[2] Bats and many species of birds such as swallows and martins can capture mosquitoes in flight.[2]

D. NATURAL PARASITES

Because the eggs, larvae and pupae of most species develop in highly contaminated water which contains a rich flora and fauna, mosquitoes are usually exposed to a variety of natural parasites at the various life stages. These parasites include microorganisms such as molds and bacteria, gregarines, flagellates, microsporidia, ciliates, trematodes, nematodes, and even mites and diptera.[2] While the effects of these organisms are a definite burden to the mosquito, they usually are not sufficient to eliminate mosquitoes except in a very highly localized condition. However, their major effect is to prevent population explosions, and well-conceived control programs will promote their growth.

E. EMPLOYMENT OF NATURAL ENEMIES FOR MOSQUITO CONTROL

1. Fish

Prior to the development of effective chemical pesticides, (and more recently in attempting to avoid their ecological effects), attempts have been made to employ various natural enemies of the mosquito in managed mosquito control programs. To date, fish have been the most successfully employed natural enemy of the mosquito.[14] Gerberich[15] prepared an annotated bibliography of papers relating to the control of mosquitoes by the use of fish, and it contained 298 references that had appeared in the literature up to 1942. The 1966 revision by Gerberich and Laird[16] contained 686 references. According to Bay,[14] 41% of the papers deal largely or exclusively with Gambusia, 8.6% with the Southeast Asian fish, Panchax, 6.5% with the common guppy and "after that few of the remaining 200 to 300 species occupy more than 2%."

The mosquitofish, Gambusia, is a natural inhabitant of fresh water in southern areas of the United States. (The taxonomy of the mosquitofish is somewhat confused but is well-discussed by George.)[17] Species of Gambusia have been transferred from the South and introduced into other areas of the country. A cold-adapted variety of G. affinis has been successfully introduced into northern regions including Ohio, Michigan and Illinois. Under proper conditions, Gambusia may give almost complete control of mosquito population.[14] However, in its native habitat in southern U.S., large numbers of Gambusia have been observed to live together with also large numbers of mosquito larvae, indicating that a natural balance has been reached. In the appendix to his thesis, George[17] also describes the dissemination of the mosquitofish in North America and its utilization in mosquito control.

In New England and other northern areas where the winters are too cold for Gambusia to survive, certain native fish are also effective in reducing mosquito populations. In brackish water (including some areas on Cape Cod in this study), the salt water killifish or mummichog, Fundulus heteroclitus, is used to destroy mosquito larvae. The effectiveness of mummichogs in controlling mosquitoes can be greatly increased by the presence of natural or artificially produced holes several feet in diameter and a few feet deep which can retain water and offer sanctuary to the population of mummichogs as the tide recedes from the salt marshes. When the tide returns, the fish are in good position to resume activity.

2. Plants

While the use of plants in mosquito control has been studied for many years,[18] the subject is a complicated one because some species are themselves pests and others can increase production of mosquitoes instead of decreasing them. However, Bay[14] believes that "next to fish, aquatic plants, where applicable, probably hold the most important practical potential for naturalistic mosquito control."

3. Other Predators, Parasites and Pathogens

The release of large numbers of bats or predacious arthropods also does not seem practical at this time and much additional research is required. Likewise most naturally occurring pathogens of mosquitoes usually attack relatively small proportions of wild populations.[19] Despite these problems research is proceeding and promising laboratory results are being obtained[20] with microsporidia[21] and nematodes by USDA researchers at Gainesville, Florida, and Lake Charles, Louisiana. Additional laboratory and field work is required before these potential control measures can be practically evaluated.

F. CONTROL BY ALTERATION OF LIFE CYCLE

1. Sterile Male Release

The release of sterile males has been successful with a limited number of other insect pests, such as the screwworm and tropical fruit flies. However, the control of mosquitoes by this method is complicated by the large numbers of species, the variation in length of life cycle, and the effects of temperature and rainfall on the time of emergence. Much more research will be needed in order to raise a large number of mosquito species economically and separate the sexes. Large numbers of sterile males have to be released to overwhelm the natural populations even when that population has been reduced by prior use of pesticides. The released males must be competitive with the males in the natural populations. At the present time it does not appear practical to control all species of mosquitoes in a given area by sterile male release but one or two especially troublesome species might be controlled in this manner.[20,22]

2. Sterilization of Males or Females in Natural Habitat

While chemical or radiation sterilization in the natural habitat is theoretically possible, we do not yet have safe and innocuous methods that would not endanger other species. Also, safe and specific attractants will be necessary to attract the wild species to the place at which they would be sterilized.

Chromosomal translocations have been studied as a method of introducing sterility into a natural population.[23] Double translocations appear to be much more effective than single translocations and have approximately the same theoretical effectiveness in reducing mosquito populations as the sterile male technique.[20] Again much laboratory and field work remains to be done.

3. Hormones

Synthetic materials which mimic hormone activity have recently been reported.[24,25,26] These products may stop the growth of mosquitoes in the larval stage or in the pupal stage and thus break the life cycle. While these materials show great promise, they are still in an experimental stage, some are easily destroyed by sunlight and it will take time to assess their true value.

4. Attractants

Sex attractants or oviposition attractants may possibly be useful in attracting adult mosquitoes to traps. Again these materials have only been partially investigated and to date no commercially available products are known which are useful with mosquitoes.

G. MECHANICAL METHODS OF MOSQUITO CONTROL

1. Drainage and Flooding

One of the most effective ways of controlling mosquito populations has been the selective and partial drainage of swampy areas to remove standing pools of water.[27] Often the number of breeding places for mosquitoes can be drastically curtailed while still not interferring with other wild life, such as ducks, fish, etc., that inhabit marshes and swamps. Conversely, where a large flow of water is obtained, either fresh water or that from tides, mosquito larvae may be swept out of the area by rapid flooding of the breeding area.[27]

2. Traps

Traps for female mosquitoes have not been well-developed, probably because of a lack of information on the specific attractants required in order to entice them into traps.

3. Screening

While screening is usually thought of as keeping female mosquitoes away from their human victims, screening can keep the female of house-dwelling mosquitoes away from areas for egg-laying.

4. Insoluble Monolayers

Biodegradable lipids or lecithin spread at the extremely low concentration of approximately 1/2 ounce per acre of water has been shown to smother pupae of several mosquito species.[28] Larvae are not asphyxiated because the lipid film is easily penetrated by the small larval spiracle, but pupae cannot pierce the film. If a cheaper source of lecithin, such as cottonseed lecithin, can be used, the method may be attractive since the material would be nontoxic and does not interfere with the transfer of oxygen from the air to water. Its use seems most appropriate for small, protected still water sites, and not for open bodies of water where wave action or tidal flow would tend to destroy the film.

H. PESTICIDE USES CONSIDERED ESSENTIAL FOR ACCEPTABLE CONTROL

In New England, control programs using natural means are already well-developed, and have reduced mosquito populations in many areas. Carefully planned and maintained ditches are used to reduce the number of pools and puddles where female mosquitoes lay their eggs. In salt marshes, holes are dug for predacious fish to provide sanctuary far from normal water channels during low tide and to insure their presence at high tide. Nesting boxes are provided for birds which prey on mosquitoes, in areas of high population probability, and encourage them to stay in the area.

Even with the use of all these methods, it is still necessary to use pesticides to gain acceptable control of mosquitoes that will prevent spread of EEE. In the critical areas of Southeastern Massachusetts, weather patterns in some seasons minimize the effects of natural controls and require frequent application of pesticides. In extreme cases wide areas need to be treated, but in normal situations only spot treatment of selected swamps and marshes is necessary. We believe that a good larvaciding program, properly conducted, will control most mosquito populations and preclude the need for adulticiding programs.

A significant feature of developing good larvaciding programs is the potential for use of nonchemical, degradable mineral oils (such as Flit MLO) which have only minor acute effects on nontarget species and minimum residual effects. Larvaciding with such products will kill or prevent larvae from developing properly by sealing off their oxygen supply. By thus breaking the life cycle, control of several generations can be effected and the control of several species potentially can be realized with one application. The major drawback of mineral oils is their tendency to disappear in 2-3 days, making retreatment necessary in periods of rainy weather.

In more difficult cases, it may be necessary to use rapidly degradable, nonresidual chemical insecticides (such as Abate, malathion, naled, carbamates) in larvaciding programs. Slow-release formulations of these materials will provide extended control for longer periods during rainy weather and reduce the number of applications necessary for acceptable control. The slow-release feature means that only small quantities are solubilized at any given time, reducing the danger of harming other organisms and not overloading the degradation system.

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